Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public Release; FOLIA/OPERA Exempt

Lower Passaic River Restoration Project

Preliminary Draft

Early Final Action Focused Feasibility Study

Appendices

PREPARED BY:

Malcolm Pirnie, Inc.
104 Corporate Park Drive
White Plains, NY 10602

FOR:

US Environmental Protection Agency
US Army Corps of Engineers
New Jersey Department of Transportation/
Office of Maritime Resources

September 2006

APPENDIX A: CONCEPTUAL SITE MODEL

LOWER PASSAIC RIVER RESTORATION PROJECT
APPENDIX A: CONCEPTUAL SITE MODEL

TABLE OF CONTENTS

1.0 Introduction 1-1
1.1 Objective of the Conceptual Site Model 1-1
1.2 Site Background 1-2
1.3 Development of Conceptual Site Model for the Study 1-3
1.4 Document Overview 1-5
2.0 River Sections 2-1
2.1 Preliminary Definition of River Sections 2-1
2.2 Updated Definition of River Sections 2-3
2.2.1 Evaluation of Salinity Data 2-3
2.2.2 Evaluation of Benthic Data 2-4
2.2.3 Evaluation of Bathymetric and Sediment Texture Data 2-5
2.3 Shoreline Characterization of the River Sections 2-7
3.0 Boundary Conditions 3-1
3.1 Dundee Dam Boundary Condition 3-1
3.1.1 River Flow at Dundee Dam 3-1
3.1.2 Surficial Sediment Chemistry at Dundee Dam 3-3
3.2 Newark Bay Boundary Condition 3-4
3.3 Other Boundary Conditions 3-6
4.0 Sediment Transport 4-1
4.1 Solids Accumulation 4-1
4.2 Erosional and Depositional Areas 4-3
4.2.1 Delineated Erosional and Depositional Areas 4-4
4.2.2 Location of Thalweg Relative to the Erosional Areas 4-5
5.0 Source Area Analyses 5-1
5.1 Preliminary Identification of Source Areas 5-1
5.2 Updated Identification of Source Areas 5-3
5.2.1 Sediment: Potential Source Area and Contaminated Media 5-5

5.2.2 Shoals: Potential Source Area and Contaminated Media 5-9
5.2.3 Water Column: Potential Source Area and Contaminated Media 5-10
5.2.4 Groundwater: Potential Source Area and Contaminated Media 5-11
5.3 Initial Mass Balance for the Lower Passaic River and Newark Bay 5-15
5.3.1 Newark Bay 2,3,7,8-TCDD Mass Balance 5-16
5.3.2 Newark Bay Mercury Mass Balance 5-17
6.0 Contaminant Fate and Transport 6-1
6.1 Nature and Extent of Contamination 6-1
6.1.1 Mercury Nature and Extent of Contamination 6-2
6.1.2 Lead Nature and Extent of Contamination 6-3
6.1.3 2,3,7,8-TCDD Nature and Extent of Contamination 6-3
6.1.4 Total PCB Nature and Extent of Contamination 6-4
6.1.5 Total DDT Nature and Extent of Contamination 6-4
6.2 Estimated Future Surface Concentrations 6-5
6.2.1 Future Surface Concentration with No Action Alternative 6-6
6.2.2 Future Surface Concentration with Target Area 1 Alternative 6-8
6.2.3 Future Surface Concentration with Target Area 1 and 2 Alternative 6-10
6.2.4 Future Surface Concentration with Target Area 3 Alternative 6-12
7.0 Future CSM Updates 7-1
7.1 Uncertainties in the CSM 7-1
7.2 Refine and Maintain the CSM 7-1
8.0 Acronyms 8-1
9.0 References 9-1

LOWER PASSAIC RIVER RESTORATION PROJECT
APPENDIX A: CONCEPTUAL SITE MODEL

LIST OF TABLES

Table 3-1: Flow Statistics for the Lower Passaic River 3-2
Table 3-2: Summary of Contaminant Concentrations Above Dundee Dam and in the Lower Passaic River 3-4
Table 3-3: Summary of Contaminant Concentrations in Newark Bay and in the Lower Passaic River 3-5
Table 3-4: Surface Water Flow on the Lower Passaic River 3-7
Table 4-1: Annual Solids Accumulation (1989-2004) RM0.9 to RM7 4-1
Table 5-1: Currently Available Data and Identified Data Gaps for Sediment Beds 5-3
Table 5-2: Currently Available Data and Identified Data Gaps for Water Column 5-4
Table 5-3: Summary of Surficial Sediment Concentration from Dundee Dam to Newark Bay 5-6
Table 5-4: Concentration Decrease between Lower Passaic River and Newark Bay Concentrations (2005) 5-9
Table 5-5: 2,3,7,8-TCDD Mass Balance for Newark Bay 5-17
Table 5-6: Mercury Mass Balance for Newark Bay 5-18
Table 6-1: Decrease in 2005 Surficial Sediment as a Factor of 1995 Surficial Sediment Concentration 6-7
Table 6-2: Estimated Future Sediment Concentration Assuming a No-Action Alternative 6-8
Table 6-3: Estimated Future Sediment Concentration Assuming Target Area 1 Alternative 6-10
Table 6-4: Estimated Future Surface Sediment Concentration Assuming Target Area 3 Alternative 6-12

LOWER PASSAIC RIVER RESTORATION PROJECT
APPENDIX A: CONCEPTUAL SITE MODEL

LIST OF FIGURES

Figure 1-1: Study Area Location Map
Figure 2-1: River Sections for the Lower Passaic River
Figure 2-2: Temporal Trends in Salinity
Figure 2-3: Trends in Cross-sectional Area and Sediment Texture
Figure 2-4: Photolog of Shoreline Conditions and Surrounding Habitat
Figure 4-1: Erosional and Depositional Areas (RM0.9 to RM7)
Figure 4-2: Percent Erosional, Depositional, or Neutral Areas by Quarter Mile
Figure 5-1: General Source & Physical Release Mechanisms for Contaminants in Sediment, Water, and Air
Figure 5-2: General Sources in Each River Section
Figure 5-3: Surface Sediment Concentrations for Dundee Dam, Lower Passaic River, and Newark Bay
Figure 5-4: Downcore Profiles of 2,3,7,8-TCDD at RM1.4, RM2.2, and RM11
Figure 6-1: Chemical Fate and Transport Processes in Transitional Section
Figure 6-2: Chemical and Biological Fate and Transport Processes in Transitional Section

LOWER PASSAIC RIVER RESTORATION PROJECT
APPENDIX A: CONCEPTUAL SITE MODEL

LIST OF ATTACHMENTS

Attachment 1:	Exposure Pathways and Receptors (Battelle, 2005)
Attachment 2:	Methodology to Evaluate Groundwater

1.0 INTRODUCTION

1.1 OBJECTIVE OF THE CONCEPTUAL SITE MODEL

A conceptual site model (CSM) expresses a site-specific contamination problem through a series of diagrams, figures, and narrative consistent with U.S. Environmental Protection Agency (USEPA) Office of Solid Waste and Emergency Response (OSWER) remedial investigation and feasibility study guidance (USEPA, 1988). These diagrams, figures, and the narrative are designed to illustrate the potential physical, chemical, and biological processes that transport contaminants from sources to receptors. A CSM is a tool for examining the contamination problem and provides the basis for identifying and evaluating the potential risks to human health and the ecosystem.

A CSM is prepared during the first step of the data quality objective (DQO) process (USEPA, 2000). The CSM continues to evolve throughout the project as historical and recently collected data are evaluated; DQOs are updated; and risk assessments are refined. Typical components of a CSM include:

- Potential contamination source area(s).[1]
- Potentially contaminated media and types of contaminants expected.
- Contaminant fate and transport mechanisms and migration pathways.
- Potential exposure pathways.
- Potential human and ecological receptors.

Together, these CSM components and the DQOs present a current understanding of the contamination problem; they outline existing data gaps and the sampling necessary to

[1] The CSM *does not* identify specific buildings, companies, or locations that are potential contaminant sources to the Lower Passaic River. Instead, general geographical areas (*e.g.*, upriver of Dundee Dam or downriver of Dundee Dam) are described as "source areas" where potential contaminant contributions may occur based on data evaluations.

address these gaps; they identify potential exposures that may result in existing human and ecological risks; and they provide guidance for future project decision-making. The CSM is a multidisciplinary tool that serves a critical project role in risk assessment, numerical model development, project and sample planning, decision making, and ultimately in choosing a remedial strategy. For this reason, a series of diagrams, figures, and a narrative may be appropriate for a complex project. These diagrams, figures, and narrative link together to present the CSM, but individually, each diagram or figure may highlight a different aspect of the project.

1.2 SITE BACKGROUND

The Lower Passaic River Restoration Project (herein referred to as the Study) is an interagency effort to remediate and restore the complex ecosystem of the Lower Passaic River, which is a 17-mile tidally influenced river located in northeastern New Jersey. The Study Area (118 square miles) is defined as the Lower Passaic River and its basin, which comprises the tidally influenced portion of the river from the Dundee Dam [River Mile (RM) 17.4] to Newark Bay, and the watershed of this river portion, including the Saddle River, Second River, and Third River (Figure 1-1)[2]. The Study Area does not include the watershed upriver of the dam or the portion of the watershed that is located in the State of New York.

From a geologic standpoint, the Study Area is located within the Triassic-aged Newark Basin portion of the Piedmont Physiographic Province. Bedrock underlying the Lower Passaic River is the interbedded red-brown sandstone and shale of the Passaic Formation. Almost the entire Passaic River Basin, including the Lower Passaic River, was subjected to glacial erosion and deposition ending with the Wisconsinan glaciation. The glaciation and immediately following fluvial action deposited stratified sand, silt, gravel, and clay in

---

[2] RM0.0, which was established for this Study, is defined by an imaginary line between two marker lighthouses at the confluence of the Lower Passaic River and Newark Bay: one in Essex County, New Jersey, just offshore of Newark and the other one in Hudson County, New Jersey, just offshore of Kearny Point.

a glacial lake covering the area. These glaciofluvial deposits overlie bedrock and underlie the Meadowlands section of the Newark Basin (Olsen *et al.*, 1984).

The Lower Passaic River, as described in the Work Plan (Section 1.2 "Site Background and History;" Malcolm Pirnie, Inc., 2005a), was heavily developed and became a focal point for the American industrial revolution in the 1800s. By the twentieth century, urban and industrial developments surrounding the Lower Passaic River, combined with associated population growth and development pressures,[3] had resulted in poor water quality, contaminated sediments, bans on fish and shellfish consumption, lost wetlands, and degraded habitats.[4] The lower six miles of the river is highly urbanized with significant development on the natural floodplains. Refer to the Section 1.4 "Community Profile" in the *Community Involvement Plan* (Malcolm Pirnie, Inc., 2006a) for discussion on population and demographics.

1.3 DEVELOPMENT OF CONCEPTUAL SITE MODEL FOR THE STUDY

A CSM for the Study was initially presented in the August 2005 version of the Work Plan (Malcolm Pirnie, Inc., 2005a). The objectives of the initial CSM were:

- To present the contamination problem of the Lower Passaic River by focusing initially on geochemical and transport processes.
- To lay the foundation and process for future CSM revisions.

The CSM is being updated as part of the Focused Feasibility Study (FFS), the human health and ecological risk assessments, and the DQO process, which is outlined in the

[3] The Study Area covers parts of the following 4 New Jersey counties: Essex, Bergen, Hudson, and Passaic. These predominately urban counties are populated by approximately 1.3 million people according to the 2000 U.S. Census (Malcolm Pirnie, Inc., 2006a).

[4] Sediment contamination in the Lower Passaic River, which is being addressed by the partner agencies, has its origin in numerous sources over the past 100 years or more. These sources may include direct discharges via spills and outfalls as well as indirect discharge through runoff, groundwater migration, and sewers. Another contamination source may originate upriver of the Dundee Dam or in the tributaries.

Quality Assurance Project Plan (QAPP; Malcolm Pirnie, Inc., 2005b), to address the contamination problem of the Lower Passaic River. The DQOs describe the Study objectives, which are:

- To characterize contaminant source areas and evaluate nature and extent of contamination.
- To evaluate hydrodynamics, sediment transport and stability, and biotic processes to assess the contaminant fate and transport in sediments, water, and biota.
- To evaluate exposure pathways and receptors for the human health risk assessment and the ecological risk assessment.
- To characterize the existing conditions of the ecosystem and ecological communities to evaluate restoration sites based on the ecological functional assessment metrics and assess injury to natural resources.
- To share pertinent data collected in support of restoration actions that may be conducted under the Natural Resource Damage Assessment (NRDA) authorities.

Updating the CSM is integral to satisfying these Study objectives, providing a description of the contamination problem in the Study Area, and guiding the target area analysis of the FFS document (refer to Appendix B "Target Area Analysis"). The objectives of this updated CSM are to synthesize observations to date from the studies conducted and evaluations completed[5] over the last year (September 2005 to September 2006) and to benchmark the current understanding of river processes, including to:

- Establish and define the three river sections of the Lower Passaic River (Freshwater River Section, Transitional River Section, and the Brackish River Section).
- Describe the boundary conditions of the Study Area, including the Dundee Dam and Newark Bay.

[5] The updated CSM synthesizes data evaluations that were published in other documents. Consequently, data gaps exist in the CSM where data from the different published documents do not overlap.

- Describe solids accumulation conditions and describe depositional and erosional areas in the Lower Passaic River.
- Estimate potential source areas and characterize contaminant inputs to the Lower Passaic River.
- Describe the fate and transport of target contaminants through preliminary mass balances.

Future iterations of the CSM should continue to integrate the plethora of existing data and the existing body of literature, the data collected during recent and future field investigations, the results of on-going analyses, modeling efforts and evaluations, and the exposure pathways and receptors noted in the *Pathways Analysis Report* (Battelle, 2005; refer to Attachment 1) with the objective of developing a comprehensive CSM that addresses all aspects of the Study.

1.4 DOCUMENT OVERVIEW

This document is divided into the following sections to articulate the CSM development and the process for maintaining, updating, and refining this CSM.

Section 1.0, INTRODUCTION: explains the objectives of the CSM, provides a brief description of the Study, and summarizes observations and findings comprising the CSM.

Section 2.0, RIVER SECTIONS: describes the division of the Lower Passaic River into three sections with different environmental characteristics; these sections are the Freshwater River Section, Transitional River Section, and Brackish River Section.

Section 3.0, BOUNDARY CONDITIONS: describes and defines the boundary conditions (Dundee Dam and Newark Bay) of the Study Area as currently understood.

Section 4.0, SEDIMENT TRANSPORT: describes the solids accumulation and sedimentation rates occurring on the Lower Passaic River.

Section 5.0, SOURCE AREA ANALYSES: describes geochemical evaluations conducted to identify contaminant inputs and media.

Section 6.0, CONTAMINANT FATE AND TRANSPORT: describes the fate and transport for chemical classes and presents preliminary mass balances for target compounds.

Section 7.0, FUTURE CSM UPDATES: outlines the process by which the CSM should be maintained, updated, and refined as the project proceeds.

Section 8.0, ACRONYMS: lists and defines the acronyms used in this document.

Section 9.0, REFERENCES: lists the references used in this document.

2.0 RIVER SECTIONS

For purposes of the Study, the CSM divides the Lower Passaic River into 3 river sections based on their relationship to the typical tidal range of the salt wedge, which is defined as the interface between the freshwater flowing downriver from Dundee Dam and the brackish waters flowing tidally upriver from Newark Bay. (Refer to Section 3.0 "Boundary Conditions" for a discussion of Dundee Dam and Newark Bay.) The predominant range of the salt wedge location within the river defines the Transitional River Section, while the Freshwater and Brackish River Sections are located above and below this typical range, respectively. The Transitional River Section extends several miles in length since the diurnal incursion of the salt wedge into the river will depend on a variety of environmental factors including tidal variation, the volume of freshwater flow in the river and tributaries, wind direction, and seasonal effects on temperature.

2.1 PRELIMINARY DEFINITION OF RIVER SECTIONS

The initial CSM (Malcolm Pirnie, Inc., 2005a) provided preliminary qualitative definitions for the Freshwater River Section, Transitional River Section, and the Brackish River Section (Figure 2-1):

<u>Freshwater River Section</u> represents the section of the Lower Passaic River where the water conditions are defined as "almost always" freshwater, or salinity values are less than 0.5 parts per thousand, or "per mil" (‰). At high tide, the salt wedge seems rarely to penetrate this section; however, the water elevations in this section may be tidally influenced. Water and solids are preferentially transported from the Freshwater Section to the Transitional Section, except perhaps during dry periods when the base flow of the river declines or during extreme tidal events. Additional water and solid delivery occurs at the confluences with the Saddle River (RM15.6) and Third River (RM11.3). Sediments tend to be characterized by coarse-grained material; low sedimentation rates in this river section tend to yield relatively thin sediment beds. The Freshwater Section likely supports a freshwater ecosystem and likely provides suitable habitat for freshwater

aquatic plants (vascular and algae), macroinvertebrates, fish, and wildlife species that forage on these prey types.

<u>Transitional River Section</u> represents the section of the Lower Passaic River between the Freshwater River Section and Brackish River Section, where the salt wedge typically ranges under predominant flow and tidal conditions. Hence, water conditions can vary from slightly brackish (*i.e.*, oligohaline with salinity values ranging from 0.5-5.0 ‰) to moderately brackish (*i.e.*, mesohaline with salinity values ranging from 5.0-18 ‰). This river section is continuously influenced by saltwater intrusion and mixing, resulting in changing water chemistry as well as flocculation and settling of dissolved organic matter and particulates. Water and solids are predominantly transported between the Transitional Section and Brackish Section due to tidal exchange; additional water and solid delivery occurs at the confluence with Second River (RM8.1). Sediment characteristics in the Transitional Section are similar to the Freshwater Section, predominantly coarse-grained material and relatively thin, fine-grained sediment beds. The habitat in the Transitional Section likely supports a mixture of freshwater and salt-tolerant ecosystems, resulting in a high diversity of flora and fauna. This river section likely provides suitable habitat for estuarine aquatic plants (vascular and algae), macroinvertebrates, fish, and wildlife species that forage on these prey types.

<u>Brackish River Section</u> represents the section of the Lower Passaic River closest to its confluence with Newark Bay, where the water conditions are defined as "almost always" moderately brackish with salinity values ranging from 5.0-18 ‰. (For comparison, ocean water has salinity values greater than 32 ‰.) At high tide, the salt wedge usually advances past the Brackish River Section and rarely stops within this section. Hence, the water elevations are heavily influenced by tides. Water and solids are transported between the Transitional River Section, Brackish River Section, and Newark Bay due to tidal exchange. Historical dredging of the Lower Passaic River has created deep channels in this river section, and the lack of recent maintenance dredging has resulted in the accumulation of thick sediment beds in these channels, which are dominated by fine-grained material. The Brackish River Section likely supports a salt-tolerant ecosystem

and likely provides suitable habitat for estuarine aquatic plants (vascular and algae), macroinvertebrates, fish, and wildlife species that forage on these prey types.

2.2 UPDATED DEFINITION OF RIVER SECTIONS

In this updated CSM, the river sections are further described with available salinity data, historical bathymetric data, sediment texture data, and benthic data. Based on these data, the Brackish Section is between RM0 and RM6, the Transitional River Section is defined between RM6 and RM10+, and the Freshwater River Section is between RM10+ and RM17.4.

2.2.1 EVALUATION OF SALINITY DATA

Salinity data were collected from 8 mooring stations between RM1 and RM10 by Malcolm Pirnie, Inc. and Rutgers University. Salinity data were collected by Malcolm Pirnie, Inc. from December 15, 2004 to September 30, 2005; however, at the time that the CSM was updated, only the buoy at RM10 was updated with the entire dataset. The remaining buoys capture salinity values between December 15, 2004 and February 21, 2005. The Rutgers University's salinity data were collected from July 8 to September 10, 2004 and November 20, 2004 to January 25, 2005 (Figure 2-2).[6]

The Rutgers University data indicated that river conditions were mesohaline (5-18 ‰) or polyhaline (18-30 ‰) downriver of RM5.3 (Figure 2-2a and 2-2b), representing brackish river conditions during December 2004 to January 2005. During the same time period, the upriver extent of the salt wedge ranged between RM5.3 and a point below RM6.7. This characterization is indicated by the presence of oligohaline (0.5-5 ‰) conditions at RM5.3 and freshwater conditions (less than 0.5 ‰) at RM6.7 (Figure 2-2c). This observation is also consistent with data collected during the winter months by Malcolm Pirnie, Inc. These data indicate that, during the winter, salinities at the RM8.5 and RM10 stations were less than 0.5 ‰ (indicative of freshwater; Figure 2-2d). The presence of freshwater at these 2 sampling locations indicates that the upriver reach of the salt wedge

[6] Salinity data from fall 2004 to spring 2005 are plotted in Figure 2-2. Salinity data were not continuously measured at all buoys, and gaps exist in the record.

was consistently below RM8.5 during these winter months. Furthermore, the salinity measured at RM8.5 and RM10 is similar in magnitude to readings of 0-0.4 ‰ observed at the U.S. Geological Survey (USGS) gauge at Little Falls, New Jersey, located upriver of the Dundee Dam (Figure 2-2e).

In contrast, during the summer months, the salt wedge was observed to extend farther upriver. For example, data collected between July 8, 2004 and September 10, 2004 at RM8 shows that river salinity was consistently at least oligohaline and was regularly mesohaline (Figure 2-2f; upper right-hand graph). These data indicate that the upriver extent of the salt wedge is above RM8. The upriver incursion of the salt wedge is likely due to low freshwater flow typical in summer. Salinity data at RM10 (presented in Figure 2-2d) was updated to show temporal trends from fall 2004 to summer 2005 (Figure 2-2g). Similar to the buoy at RM8, oligohaline conditions (approximately 4 ‰) are detected during the summer months. Since no salinity data are available beyond RM10, a data gap exists. Hence, the preliminary boundaries of the Transitional River Section have been defined to encompass the seasonal variation in the upriver range of the salt wedge location between RM6 and RM10+. The Brackish and Freshwater River Sections are then defined as occurring between RM0 and RM6 and between RM10+ and RM17.4, respectively. Note that these boundaries are preliminary and are based on limited salinity data; additional salinity data are warranted to better characterize the migration of the salt wedge in the Lower Passaic River.

2.2.2 Evaluation of Benthic Data

Salinity levels in the river water will dictate the predominant habitat in a river section. In the initial CSM (Malcolm Pirnie, Inc., 2005a), the Freshwater River Section was expected support a freshwater ecosystem and provide suitable habitat for freshwater aquatic plants (vascular and algae), macroinvertebrates, fish, and wildlife species that forage on these prey types. Conversely, the Brackish River Section was expected to support a brackish ecosystem and provide suitable habitat for salt-tolerant aquatic plants (vascular and algae), macroinvertebrates, fish, and wildlife species that forage on these prey types. However, the available salinity data indicates an extensive seasonal migration of the salt wedge, which will likely result in a range of organisms residing along the Lower Passaic River.

Coincident with the salinity data, the benthic invertebrate community survey conducted in June 2005 by Germano & Associates, Inc. reflects a range of benthic organisms residing along the river. Note that this benthic survey was conducted in the summer months when oligohaline conditions were observed at RM10 (Figure 2-2g). The results of the survey indicate that salt-tolerant benthic organisms, which typically reside in polyhaline environments, were predominantly located from RM0 to RM1. A mixture of organisms that typically reside in mesohaline and oligohaline environments was observed from RM1 to RM7 while a mixture of organisms that typically reside in oligohaline and freshwater environments was observed from RM7 to RM15.5 (data gap exists above RM15.5).

2.2.3 Evaluation of Bathymetric and Sediment Texture Data

While a salinity data gap exists above RM10, the available salinity data at RM8 and RM10 (Figure 2-2d and Figure 2-2g) suggest the extent of the salt wedge appears to seasonally extend upriver of RM10. In an attempt to estimate the furthest upriver extent of the salt wedge, an evaluation of bathymetric data and sediment texture data was completed. (Note that the boundaries of the Transitional River Sections are defined by salinity, and the following discussion is presented only to provide some insight on the furthest upriver extent of the salt wedge. Additional salinity data are necessary to define completely the Transitional River Section.) Together, the sediment texture and bathymetric datasets may provide an indication of the upper salt wedge excursion because resuspension and deposition of fine-grained sediments occurs in the Transitional and Freshwater River Sections mainly along the salt wedge. In addition, other mechanisms may contribute to the resuspension and deposition of solids. For example, deposition of fine-grained sediments also occurs due to the change in river velocity during slack tide, from the natural loss of river energy due to friction, or the change in channel geometry. In addition, tidal effects can transport resuspended solids as far as the head of tide, which may be located further upriver than the salt wedge (known as the "siltation process"); however, this process contributes minimally to sediment transport.

To begin, the cross-sectional area of a river increases downriver as increasing flow and tidal currents serve to widen the river channel. As the cross-sectional area increases, the river velocity tends to decrease, resulting in the deposition of fine-grained sediments. As expected, the cross-sectional area of the Lower Passaic River increases downriver from RM16.5 (near Dundee Dam) to RM0.5 (near the mouth of the river).[7] A plot of cross-sectional area versus river mile shows a 40 fold increase in area, occurring exponentially along the length of the Lower Passaic River (Figure 2-3a; cross-sectional areas constructed every half mile). This exponential function is characterized with a linear regression coefficient (R^2) of 0.92 and a midpoint at RM6.5. The cross-sectional areas displayed in this plot represent the vertical area flooded across the river channel when water level is equal to zero feet at National Geodetic Vertical Datum of 1929 (NGVD29).

The cross-sectional areas were then compared to the sediment texture to characterize the grain size distribution in surficial sediment.[8] For each half-mile stretch of the Lower Passaic River, a percentage was calculated to represent the surficial river bottom area that was covered by fine-grained sediments (classified as silt and silt/fine sand by the side-scan sonar images), medium-grained sediments (classified as sand), and coarse-grained sediments (classified as gravel/coarse sand and rock/coarse gravel). Figure 2-3b exhibits the percentage of fine-grained sediment and percentage of coarse-grained sediment versus the corresponding cross-sectional area. A striking feature in this plot is the distinct transition from coarse-grained to fine-grained sediments between RM14 and RM8 as the cross-sectional area increases from 2,500 to 3,500 square feet. Downriver of

---

[7] Cross-sectional areas (unit of square feet) calculated using the 2004 bathymetry surveyed by Rogers Surveying, Inc. for the U.S. Army Corps of Engineers (USACE). While the dataset extends from RM0 to RM17.4, cross-sectional areas were not constructed above RM16.5 since no accompanying sediment texture data were available for comparison.

[8] Sediment texture was evaluated based on data interpolated by Aqua Survey, Inc. using side-scan sonar images (Aqua Survey, Inc., 2006). Sediment texture data extends from RM0 to RM16.5.

RM8, the surficial sediment is dominated by fine-grained sediments with silts and fine sands covering more than 80 percent of the surveyed area. Upriver of RM14, the surficial sediment is dominated by coarse-grained sediment with 100 percent of the surveyed area between RM15 and RM16.5 classified by side-scan sonar images as gravel/coarse sand and rock/coarse gravel. This coarse-grained surficial sediment extends to the Dundee Dam (RM17.4) based on field observations of the river near the dam during the reconnaissance that occurred between December 2004 and February 2005 (Earth Tech, Inc. and Malcolm Pirnie, Inc., 2005).

The grain size distribution suggests that the upriver extent of the salt wedge ranges between RM8 to RM14; as discussed above, the salt wedge probably extends beyond RM10 seasonally. Thus, the upriver extent of the salt wedge may extend to RM14 under low river flow conditions. The grain size distribution also indicates that the salt wedge rarely extends upriver of RM14 due to the presence of coarse-grained sediments above RM14. Moreover, while the head of tide extends to the Dundee Dam and suspended solids may be transported to the dam by the siltation process, the energy of the freshwater river flow over the dam is high enough to prevent fine-grained sediments from permanently depositing.

2.3 SHORELINE CHARACTERIZATION OF THE RIVER SECTIONS

As part of the CSM, the river sections were further described in terms of their shoreline conditions and surrounding habitats. This characterization was accomplished using photographs that were collected during field reconnaissance activities [refer to the *Restoration Opportunities Report* (Earth Tech, Inc. and Malcolm Pirnie, Inc., 2006)]. Selected photographs from the reconnaissance are presented in Figures 2-4a through 2-4e. The shoreline and land use conditions vary considerably among the Brackish, Transitional, and Freshwater River Sections. The Brackish River Section is characterized by industrial and urban lands, typically with hardened shorelines comprised of bulkheads or riprap (Figure 2-4a and Figure 2-4b). The Transitional River Section is largely surrounded by residential communities; accordingly, the river shoreline in this area typically features natural riverine vegetation (Figure 2-4c). The Freshwater River Section is the least industrialized of the three river sections and features the lowest density of development. This Freshwater River Section is also characterized by shorelines with natural vegetation communities, often with overhanging tree canopies (Figure 2-4d). Traveling upriver in the Freshwater River Section, the river gradually transitions from a wide, slowly-flowing river to a narrower and more swiftly-flowing stream above RM15 with a substrate composed of rock and coarse gravel (Figure 2-4e).

Further discussion on the available biological and ecological data for the Lower Passaic River is provided in Section 3.0 "Field Task Status" of the Field Sampling Plan, Volume 2 (Malcolm Pirnie, Inc., 2006b).

3.0 BOUNDARY CONDITIONS

For purposes of the Study, the CSM has two main boundary conditions: the Dundee Dam, where freshwater and solids flow into the Freshwater River Section, and Newark Bay, where the brackish bay water interacts with the Brackish and Transitional River Sections during each tidal cycle (Figure 2-1). Other boundary conditions, such as tributaries and combined sewer overflow (CSO) sites, also impact the Lower Passaic River by contributing water, solids load, and contaminant mass.

3.1 DUNDEE DAM BOUNDARY CONDITION

The Dundee Dam represents the upper boundary of the Lower Passaic River. The dam is located at RM17.4 between Garfield and Clifton, New Jersey. The Dundee Dam is the effective upriver limit of the tide for the Lower Passaic River under all known conditions, and the water flowing over the dam is made up entirely of freshwater from upriver.

3.1.1 RIVER FLOW AT DUNDEE DAM

Flow at the dam is currently estimated using a USGS gauging station located at Little Falls, New Jersey (approximately 12 miles upriver of the Dundee Dam). To estimate the average river flow at Little Falls, the yearly average flows from 1898 to 2005 were averaged; however, this flow value was approximately 8 percent higher than the average flow calculated for the last 10 years. The average river flow at Little Falls from 1995 to 2005 was 1,040 cubic feet per second (cfs). The average flow from the Little Falls gauge must be adjusted by 10 percent to account for the additional watershed area between Little Falls and the Dundee Dam,[9] yielding an average river flow at the Dundee Dam of 1,150 cfs.

[9] River flow at Dundee Dam is based on a July 18, 2005 electronic message from Emad Sidhom (Senior Project Engineer at United Water and the New Jersey District Water Supply Commission) to F. Chris Purkiss (Malcolm Pirnie, Inc.).

River flow on the Lower Passaic River can be further characterized by examining the variation in flow, or examining extreme flow events such as high flow events and low flow events, and by observing whether the variation of flow has changed over time. River flow statistics for the Lower Passaic River are presented in Table 3-1. This table provides flow data for a 6-year time period from 1995 to 2001 and flow data for the past 50 years. Since the watershed characteristics of the Upper Passaic River (near the Little Falls gauging station) have changed during the last century, it was deemed more appropriate to compare the 1995-2001 river flows to those flows for the last 50 years instead of the entire 1898-2005 dataset. (In this evaluation, the period of record from 1995 to 2001 was selected for temporal consistency with the erosional/depositional analysis that is presented in Section 4.2 "Erosional and Depositional Areas" and Appendix B "Target Area Analysis.")

Table 3-1: Flow Statistics for the Lower Passaic River

Year	Annual Total River Flow (billion gallons per year) [a]	Annual Peak River Flow (billion gallons per day) [a]
1995	155	3.1
1996	426	6.0
1997	198	3.2
1998	261	5.7
1999	195	7.3
2000	216	2.2
2001	167	2.9
Average from 1995 to 2001	231	4.3
Average from 1956 to 2005	247	4.5
Minimum from 1956 to 2005	64	2.0
Maximum from 1956 to 2005	453	11.7

a: Data source: U.S. Geological Survey National Water Information System (http://waterdata.usgs.gov/nwis/dv/?referred_module=sw). The site is 01389500 Passaic River (Little Falls, New Jersey).

In general, the average river flow and average peak flow between 1995 and 2001 are comparable to the average river flow (247 billion gallons) and the average peak flow (4.5 billion gallons per day) between 1956 and 2005 (Table 3-1). Moreover, during the time period of 1995 to 2001, the Lower Passaic River experienced both relatively wet and dry years. For example, the year 1995 was relatively dry, receiving approximately half the average annual river flow based on the period of 1956 to 2005. However, this 1995 flow was not as low as the minimum annual flow reported for the past 50 years, reported as 64 billion gallons. In addition, the 1995 peak flow was well below the average 1956 to 2005 peak flow. Conversely, the year 1996 was relatively a wet year (426 billion gallons per year), not only compared to the average annual flow but also compared to the maximum annual flow of 453 billion gallons for the 50-year record. Meanwhile, the year 1999 experienced less than average annual flow (195 billion gallons) but experienced above average 1956-2005 peak river flow (7.3 billion gallons per day), which is likely associated with Tropical Storm Floyd. Hence, in the time period of 1995-2001, high flow events and low flow events that were recorded on the Lower Passaic River are typical of those river flows experienced on the river over the past 50 years.

3.1.2 Surficial Sediment Chemistry at Dundee Dam

Surficial sediment chemistry above Dundee Dam was characterized in 1986 with a high resolution sediment core[10], collected by Bopp *et al.* (2006). These surficial sediments, representing the time horizon of 1985-1986, were analyzed for 4 metals (lead, copper, cadmium, and mercury) and 3 organic compounds [polychlorinated biphenyls (Total PCB), dichlorodiphenyltrichloroethane and its metabolites (Total DDT), and 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)]. In general, the metals concentrations and mass fractions that were observed above the Dundee Dam in 1985-1986 are comparable to the corresponding metals concentrations and mass fractions observed below the dam in 1995 in the Lower Passaic River (RM0.9 to RM7)[11]. These data suggest that Upper Passaic River is contributing a significant load of lead, mercury, and cadmium to the Lower Passaic River. Conversely, the concentrations of the organic compounds detected in the core above the dam are less than the corresponding concentrations reported below the dam in the Lower Passaic River. However, the Upper Passaic River still accounts for one-third to one-fourth of the contaminant load for Total DDT and Total PCB in the Lower Passaic River. Table 3-2 summarizes these data [excerpt from *Draft Geochemical*

---

[10] A high resolution sediment core is a finely-segmented core collected from a depositional area in the river. If continuously depositional, the core segments can be dated through comparison of radioisotope measurements to known radiochemical events and trends. When analyzed for specific contaminants, the individual dated segments can be used to infer contaminant loads borne by the river.

[11] Surficial sediment represents 0-6 inches in the Lower Passaic River (1995 Tierra Solutions, Inc. dataset).

Evaluation (Step 2) (Malcolm Pirnie, Inc., 2006c)]; refer to Section 5.0 "Source Area Analyses" for further discussion on a potential source area upriver of the Dundee Dam.

Table 3-2: Summary of Contaminant Concentrations Above Dundee Dam and in the Lower Passaic River

Analyte (units) [a]	Lower Passaic River 1995 Concentration [b, c]	Dundee Dam 1985-1986 Concentration [d]
Cadmium (mg/kg)	5.1 ±3.1 (N = 95)	4.2
Copper (mg/kg)	230 ±250 (N = 95)	120
Lead (mg/kg)	330 ±150 (N =90)	307
Mercury (mg/kg)	3.3 ±1.9 (N = 92)	1.8
Total PCB (μg/kg) [e]	1,300 ±1,800 (N = 90)	480
Total DDT (μg/kg) [e]	300 ±740 (N = 95)	68
2,3,7,8-TCDD (μg/kg)	0.81 ±2.0 (N = 95)	0.02

a: Excerpt from the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c).
b: Arithmetic average and standard deviation (± 1 sigma) based on a normal distribution with sample size (N) for RM0.9 to RM7 (Tierra Solutions, Inc., 1995); nondetected values are incorporated into the average as half the reported detection limit.
c: 1995 surface concentrations are defined as 0-0.5 foot. Samples include depositional and non-depositional environments; hence, the temporal component of these samples is less constrained than the literature values corresponding to 1985-1986.
d: Reported literature values (Bopp *et al.*, 2006; Bopp *et al.*, 1991a, Bopp *et al.*, 1991b), representing 1985-1986 surficial sediment concentraitons.
e: Total PCB represents the sum of Aroclors, and Total DDT represents the sum of the 4,4′-series [refer to the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c)].

3.2 NEWARK BAY BOUNDARY CONDITION

Newark Bay represents the lower boundary of the Lower Passaic River. The bay (6 miles long and 1 mile wide) is part of the New York / New Jersey Harbor Estuary and is heavily influenced by tides. Newark Bay is located at the confluence of the Lower Passaic River and the Hackensack River; the bay is linked to the Upper New York Bay by the Kill van Kull and to the Lower New York Bay by the Arthur Kill. A solids mass balance performed by Lowe et al. (2005) indicated that Newark Bay receives solids from all these waterbodies (72 percent from the Kills, 23 percent from the Lower Passaic River, 2 percent from the Hackensack River, and 3 percent from other sources) and that solids are only removed from Newark Bay during maintenance dredging. Both the eastern and western banks of Newark Bay are dominated by numerous active and abandoned commercial and industrial properties. These banks are extensively developed and consist of miles of paved shoreline (Battelle, 2006). Refer to Section 5.3 "Initial Mass Balance for the Lower Passaic River" for discussion on solids mass balance and the accumulation of solids in Newark Bay.

Newark Bay and its tributaries have been subjected to expanding urban and industrial development, resulting in a dramatic degradation of the Newark Bay area. Surficial sediment chemistry in Newark Bay was characterized in 2005 during the low resolution sediment core program,[12] which was developed to support the Phase 1 Remedial Investigation of Newark Bay [conducted by Tierra Solutions, Inc. (TSI); data available in the initial May 2006 data transmittal; pesticide data not available in this transmittal].[13] As part of this program, low resolution sediment cores were collected from 69 sampling locations. Among these locations, 35 sampling locations were identified as occurring within a depositional environment (includes locations within the authorized federal navigational channel and within port channels).[14] Table 3-3 characterizes the surficial sediment (0-6 inches) in the depositional environments that were located in the main body of Newark Bay but excluding locations in the port channels, yielding 21 sampling locations. These values are compared to the Lower Passaic River (same data as Table 3-2); refer to Section 5.0 "Source Area Analyses" for further discussion on the interactions between the Lower Passaic River and Newark Bay. In general, average surface concentrations in Newark Bay are less than average surface concentrations in the Lower Passaic River, respectively, implying that Newark Bay is not an input of contamination to the Lower Passaic River but a receiver of solids from the river.

Table 3-3: Summary of Contaminant Concentrations in Newark Bay and in the Lower Passaic River

Analyte (units)	Lower Passaic River 1995 Concentration [a, b]	Newark Bay 2005 Concentration [c,d]
Cadmium (mg/kg)	5.1 ±3.1 (N = 95)	0.93 ±0.56 (N =23)
Copper (mg/kg)	230 ±250 (N = 95)	98 ±24 (N = 21)
Lead (mg/kg)	330 ±150 (N =90)	97 ±23 (N = 23)
Mercury (mg/kg)	3.3 ±1.9 (N = 92)	1.5 ±0.69 (N = 23)
Total PCB (µg/kg) [e]	1,300 ±1,800 (N = 90)	410 ±140 (N = 21)
2,3,7,8-TCDD (µg/kg)	0.81 ±2.0 (N = 95)	0.053 ±0.029 (N = 23)

[12] A low resolution sediment core is a coarsely-segmented core that records the general chemistry of the river sediment. In some cases, the cores may provide data to approximate contaminant load (time-scale of decades).

[13] The entire dataset is available from the following website: www.ournewarkbay.org.

[14] Surficial sediment (0-1 inch) had detectable beryllium-7 concentrations that were greater than 0.5 pCi/g.

Table 3-3 (continued)

a: Arithmetic average and standard deviation (± 1 sigma) based on a normal distribution with sample size (N) for RM0.9 to RM7 (Tierra Solutions, Inc., 1995); nondetected values are incorporated into the average as half the reported detection limit.
b: 1995 surface concentrations are defined as 0-0.5 foot. Samples include depositional and non-depositional environments.
c: Arithmetic average and standard deviation (± 1 sigma) based on a normal distribution with sample size (N) for Newark Bay (Tierra Solutions, Inc., 2005); nondetected values are incorporated into the average as half the reported detection limit.
d: 2005 surface concentrations are defined as 0-0.5 foot. Samples include depositional sampling locations outside the port channels (*e.g.*, in the main body of Newark Bay).
e: Total PCB for the Lower Passaic River represents the sum of Aroclors [refer to the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c)]. Total PCB for Newark Bay represents the sum of 168 available PCB congeners (nondetected concentrations incorporated into the summation as zero).

3.3 OTHER BOUNDARY CONDITIONS

While Dundee Dam and Newark Bay are the two main boundary conditions, other boundaries continue to impact the water and sediment quality on the Lower Passaic River. These boundaries include major tributaries (Saddle River, Second River, and Third River), minor tributaries (Frank's Creek, Lawyer's Creek, Harrison Creek, and Plum Creek), storm sewers, CSO sites, known New Jersey Pollution Discharge Elimination System (NJPDES) sites, and discharging groundwater (refer to Section 5.2.4 "Groundwater: Potential Source Area and Contaminated Media"). Each of these boundaries will contribute or exchange water, solids load, and contaminant mass with the Lower Passaic River. Note that although the tributaries are incorporated into the Study Area (refer to Section 1.2 "Site Background" for definition), the main focus of this updated CSM and the FFS is on the main stem of the Lower Passaic River. Processes occurring on the tributaries do not appear to be as significant as the water, solids load, and contaminant mass exchanging and impacting the Lower Passaic River. Therefore, the tributaries are considered a boundary condition in this version of the CSM.

While the chemical contributions and solids load of these boundaries have not been fully quantified at the time that this document was written, the volume of surface water for each *gauged* boundary condition has been estimated (refer to Attachment 2 for calculations). Table 3-4 summarizes the surface water flows on the Lower Passaic River at gauged boundaries. While the flows from the tributaries and known discharges are approximately 15 percent of the flow over Dundee Dam, the contaminant load across these boundaries compared to the contaminant load over the dam is uncertain.

Table 3-4: Surface Water Flow on the Lower Passaic River

Gauged Boundary Condition	Flow Rate [a] (cubic feet per second)
Dundee Dam	1,150
Saddle River	108
Third River	19
Second River	22
NJPDES Flows	27

a: Refer to Attachment 2 for calculations and more information

4.0 SEDIMENT TRANSPORT

As previously reported, the Lower Passaic River is dynamic, experiencing both years of net erosion and years of net deposition [refer to Section 3.0 "Sediment Transport" in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) for further discussion]. Solids are introduced to the Lower Passaic River from above the Dundee Dam, tributaries, and discharge points; mixed and re-worked through tidal mixing and during erosional and depositional events; eventually transported through the 3 river sections; and deposited in Newark Bay. The following sections describe sediment transport in the Lower Passaic River by analyzing solids accumulation and erosion/deposition activity.

4.1 SOLIDS ACCUMULATION

To evaluate the annual solids accumulation in the Lower Passaic River (RM0.9 to RM7), historical bathymetric surveys were evaluated. For this evaluation, available historical surveys (1989 through 2004) were considered in a series of 10 comparisons [refer to Section 2.1 "Sedimentation Rates and Annual Accumulation" in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) for description of methodology]. Annual solids accumulation ranged from a loss of 166,000 cubic yards (representing a year of net erosion) to a gain of 144,000 cubic yards (representing a year of net deposition). The results are presented in Table 4-1.

Table 4-1: Annual Solids Accumulation (1989-2004) RM0.9 to RM7

Time Period	Rounded Annual Accumulation (cubic yards) [a,c]
1989-1995	16,800 [b]
1995-1996	144,000
1996-1997	-23,100
1997-1998	47,200
1998-1999	47,200
1999-2000	60,600
2000-2001	60,600
2001-2002	-166,000 [d]
2002-2003	99,800
2003-2004	99,800

Table 4-1 (continued)

a: The actual uncertainty in these estimates of annual accumulation is unknown. However in the absence of any actual change, a one-inch offset in the vertical reference plane between any two surveys would represent a volume equivalent to about 36,000 cubic yards.
b: 16,800 cubic yards represents the average annual accumulation for 6 years; the total accumulation from 1989-1995 is 100,800 cubic yards.
c: Excerpt from *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c).
d: The large delta may be the result of a change in surveying companies and a change in the vertical reference level. Refer to the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c).
e: Adjacent years with identical annual accumulations rates represent surveys conducted two years apart with the net difference apportioned annually.

In general, "wet" years with high river flow (not peak river flow values) will correspond to years of lower depositional rates or perhaps erosion while "dry" years with low river flow will correspond to years of higher depositional rates. River statistics for the Lower Passaic River are available for the years 1995 to 2001 (Table 3-1). In the year 1996, the river experienced a "wet" year with above average river flow (426 billion gallons per year). This high flow event corresponds to a net loss of solids from the Lower Passaic River to Newark Bay. Meanwhile, the year 1995 was a "dry" year with below average river flow (155 billion gallons per year), which corresponds to the net gain of solids on the river. Note that while an apparent correlation exists between the solids accumulation presented in Table 4-1 and the river flow values presented in Table 3-1, the uncertainties in the bathymetric data need to be considered. For example, the change in surveying companies between 2001 and 2002, the uncertainty in the solids accumulation value of ±36,000 cubic yards, and the non-consecutive bathymetric datasets may hamper a direct year-to-year correlation between river flow and solids accumulation.

Recent work by Lowe *et al.* (2005) provides additional information on solids load on the Lower Passaic River. Their work suggests that the solids load to the Lower Passaic River, including the flow over the Dundee Dam as well as the tributaries of the Lower Passaic River, is roughly 79,000 cubic yards/year. The Lowe *et al.* study, however, did not examine solids deposition in the Lower Passaic River, itself. In an effort to complete this calculation and to estimate the solids load at the mouth of the Passaic River, the 1989 and 2004 bathymetric surveys were compared from RM0 to RM15. (These two surveys were compared because bathymetric data extend to RM15; however, because of the 15 year time span between surveying events, any extreme depositional or erosional events are averaged out.) This comparison yielded annual solids accumulation of 67,000 cubic yards for RM0 to RM15. However, a further refinement of this analysis revealed that a large percentage of this solids load occurs in RM0 to RM7.

The surficial sediment texture in the Lower Passaic River is consistent with this observation with coarse-grained sediment present above RM14 and fine-grained sediments dominating the lower stretch of the river (Figure 2-3). [Note that if the entire annual accumulation (67,000 cubic yards) were to occur in RM0 to RM7, this accumulation would yield an annual deposition rate of roughly 1 and a half inch/year.] While the Lower Passaic River is experiencing a net deposition of sediment (for the period examined), a solids mass balance indicates that upriver solids are still transported through the Lower Passaic River into Newark Bay and potentially beyond. Based on this solids mass balance, an estimated 20 to 50 percent of the upriver solids are eventually transported out of the Lower Passaic River to Newark Bay each year.

4.2 EROSIONAL AND DEPOSITIONAL AREAS

The solids load is transported through the Lower Passaic River from the Dundee Dam to Newark Bay through tidal mixing and a series of erosion and deposition events. A detailed examination of sediment deposition rates indicates a high degree of spatial heterogeneity in the Lower Passaic River [refer to Section 3.0 "Sediment Transport" in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) for further discussion]. To identify consistently erosional and depositional areas in RM0.9 to RM7, a separate evaluation was completed using historical TSI bathymetric data (surveyed by Ocean Surveys, Inc. in 1995, 1996, 1997, 1999, and 2001), which cover a 6-year time period.[15] The TSI surveys were selected because the bathymetric surveying tracks are well aligned, reducing the uncertainty in direct measurement-to-measurement comparisons. (Refer to Appendix B "Target Area Analysis" of this FFS document for

[15] Erosional and depositional areas were not delineated above RM7 due to a lack of consecutive bathymetric datasets.

details on the methodology and further discussion.) The interpreted bathymetric surveys cover a time period (1995-2001) where the Lower Passaic River experienced both relatively "wet" years and relatively "dry" years (Table 3-1). Since the period from 1995 to 2001 includes conditions reasonably representative of high flow events and low flow events on the Lower Passaic River, an evaluation of bathymetric surveys from 1995 to 2001 likely characterizes the general behavior of the river and should permit the accurate identification of locally erosional and depositional areas.

4.2.1 DELINEATED EROSIONAL AND DEPOSITIONAL AREAS

Delineated erosional areas and depositional areas are based on the 1995 through 2001 bathymetric data and presented in Figure 4-1. The limited appearance of erosional areas in the Lower Passaic River (RM0.9 to RM7) is anticipated since the river tends to experience net deposition. Previous solids load calculations estimate that 60 to 80 percent of the solids originating upriver are deposited in RM0 to RM7 (refer to Section 4.1 "Solids Accumulation").

While the sedimentation rates on the Lower Passaic River are heterogeneous, some stretches of the river could be described as more erosional than depositional. This categorization can be ascertained by examining the fraction of the area that is depositional, erosional, or neutral within quarter-mile (bank-to-bank) units. Figure 4-2 is a linear plot that presents the percent erosional and depositional areas per quarter mile that are displayed on the maps in Figure 4-1. This linear plot distills the information provided in Figure 4-1 to describe depositional and erosional areas. Deposition accounts for more than 80 percent of the area near RM0.9 and in parts of the area between RM2.5 and 3.5. While depositional areas are still common between RM3.5 and RM5, erosional areas account for more than 20 percent of the area at certain points. Upriver of RM5, depositional and neutral areas again become prevalent. Note that neutral areas (*i.e.*, areas that experience both deposition and erosion) account for approximately 35 percent of the area from RM0.9 to RM7, re-emphasizing the dynamic nature of the river.

4.2.2 LOCATION OF THALWEG RELATIVE TO THE EROSIONAL AREAS

In general, erosional areas occur on the outer bank of a meandering river. It is also anticipated that the river velocity will be faster in areas where the river channel is narrow, resulting in more erosion. To approximate the location of the thalweg, a line defining the lowest elevation along the length of a river was constructed (Figure 4-1). As expected, the erosional areas that were identified during the bathymetric compilations frequently occur on the outer banks of the meandering river. For example, erosional areas occur between RM1.8 and RM2.4 as the river bends from north-south to east-west. Erosional areas become prominent again between RM3.3 and RM5.1 as the river bends in an S-shape and the thalweg crosses from the left-bank descending to the right-bank descending at RM3.7. Sporadic erosional areas then appear upriver of RM5.4 as the thalweg adjusts for the presence of bridges. As the river makes another slight bend towards the northeast between RM6.0 and RM6.7, erosional areas occur again on the outer bank.

5.0 SOURCE AREA ANALYSES

Development of the CSM involves examination and representation of potentially contaminated media, source areas, and potential migration pathways. For the CSM of the Lower Passaic River, each of the three river sections (described in Section 2.0 "Establishment of River Sections") has been further subdivided into three media: sediment, water, and air (Figure 5-1). These media interact through various natural processes and are impacted by various contamination source areas. A schematic flow diagram is presented in Figure 5-1 to describe how these media and source areas interact. In Figure 5-1, the different media are marked with different colors (sediment marked as brown, water marked as dark blue, and air marked as light blue), source areas or inventories are denoted in boxes, and release mechanisms or fluxes are marked on the arrows connecting associated inventories.[16]

While the schematic in Figure 5-1 illustrates how potential source areas and media will interact, some source areas denoted on this figure will be absent or less significant within a given river section. However, since limited data are available to assess all these sources in each river section, the list of potential source areas is repeated for each river section (Figure 5-2). Future revisions of the CSM should update the list of potential source areas and highlight the relevant source areas for each river section.

5.1 PRELIMINARY IDENTIFICATION OF SOURCE AREAS

The initial CSM (Malcolm Pirnie, Inc., 2005a) identified a preliminary list of potential source areas to the water column and sediment beds of the Lower Passaic River (Figure 5-1 and Figure 5-2).

[16] In Figure 5-1, the arrow length does not reflect the magnitude of the flux. Relevant inventories were incorporated into Figure 5-1; however, future CSM iterations will prioritize these sources and fluxes based on river section.

<u>Sediment Beds</u>: are impacted and influenced by several potential contaminant migration pathways through the environment, including:

- Transport and deposition of solids originating above the Dundee Dam.
- Resuspension and deposition of solids due to flow and tidal exchange with adjacent river sections.
- Resuspension and deposition of solids due to tidal flow within the section.
- Transport and deposition of solids from the tributaries to surface sediment.
- Discharge and subsequent deposition of solids from non-point sources, including runoff and deposition to surface sediment.
- Discharge of solids from point sources, including CSO sites, wastewater treatment plant (WWTP) sites, as well as permitted and accidental releases to the surface sediment.
- Burial of surficial sediment to intermediate sediment beds and deep sediment beds from sedimentation and bioturbation.
- Resuspension and deposition of solids between mudflats and floodplains and the surface sediment.
- Interactions with porewater and groundwater discharges.
- Remobilization of intermediate and deep sediment beds during floods or storm events.

<u>Water column</u>: is impacted and influenced by several potential contaminant sources and transport mechanisms, including:

- Main-stem flow originating above the Dundee Dam.
- Flow and tidal exchange with adjacent river sections.
- Discharge of water from tributaries.
- Discharge and runoff of water from non-point sources.
- Discharge of water from point sources, including CSO sites, WWTP sites, as well as permitted and accidental industrial releases.
- Exchange between porewater and the water column from tidal pumping, diffusion, and bioturbation.

- Discharge and seepage of groundwater to the water column.
- Atmospheric wet deposition, atmospheric dry deposition, and volatilization to the atmosphere.

5.2 UPDATED IDENTIFICATION OF SOURCE AREAS

In this updated CSM, the above preliminary list of source areas is updated based on available historical data and field data collected in 2005 and 2006 by Malcolm Pirnie Inc. as part of the USEPA field collection program and by TSI as part of the Phase 1 Remedial Investigation of Newark Bay. Based on these data and the evaluations completed in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c), the status of these source areas is provided in Table 5-1 and Table 5-2.

Table 5-1: Currently Available Data and Identified Data Gaps for Sediment Beds

Potential Source Area to Sediment Beds	Currently Available Data and Identified Data Gaps
Transport of solids originating above Dundee Dam	• Limited data on solids transport over dam; refer to Section 4.1 on solids load. • Data gap in sediment chemistry above Dundee Dam post-1985. • Refer to Section 5.3 on Dundee Dam as part of mass balance.
Resuspension and deposition of solids due to tides	• Limited data on suspended solids collected during dredge pilot study (December 2005). • Refer to Section 3.2 on Newark Bay sediment chemistry. • Refer to Section 5.3 on Newark Bay as part of mass balance.
Resuspension and deposition of solids from tributaries	• Limited data on suspended solids collected on tributaries in 2005 by Malcolm Pirnie, Inc. • Data gap in sediment chemistry from tributaries.
Discharge of solids from non-point sources	• Data gap in solids from non-point sources. • Estimates by Lowe *et al.*, 2004.
Discharge of solids from point sources	• Data gap in solids from point sources. • Estimates by Lowe *et al.*, 2004.
Burial of surficial sediment to deep sediment beds	• Refer to Section 4.0 on sediment transport. • Bathymetry data from RM0 to RM17.4 limited to 1989 and 2004 surveys. • Refer to Section 5.3 on solids as part of mass balance.
Resuspension and deposition on mudflats	• Limited sediment chemistry data on shoals (refer to Section 5.2.2). • Data gap in deposition rates and sediment chemistry on mudflats.

Table 5-1 (continued)	
Resuspension and deposition on floodplains	• Data gap in sediment chemistry from floodplains.
Interactions between sediment, groundwater, and porewater	• Refer to Section 5.2.4 on groundwater analysis interactions. • Data gap for porewater conditions.
Remobilization of sediment due to floods	• Suggestive evidence from historical bathymetric surveys. • Modeling analysis by HydroQual, Inc. is on-going.

Table 5-2: Currently Available Data and Identified Data Gaps for Water Column

Potential Source Area to Water Column	Currently Available Data and Identified Data Gaps
Main-stem flow originating above the Dundee Dam	• Refer to Section 3.1 for Dundee Dam flow. • Data gap in water chemistry, solid chemistry, and suspended solids load above dam.
Tidal exchange with adjacent river sections	• Refer to Section 2.2 for river section definition. • Large and small volume water samples collected in 2005 by Malcolm Pirnie, Inc. on the Lower Passaic River. • Semi-permeable membrane devices deployed in 2005 by Malcolm Pirnie, Inc. on the Lower Passaic River. • Limited data available on tidal exchange volume. • Data gap in water chemistry in Newark Bay.
Discharge of water from tributaries	• Refer to Section 3.3 for tributary flow. • Tributary water collected in 2005 by Malcolm Pirnie, Inc. (limited in temporal extent). • Semi-permeable membrane devices deployed in 2005 by Malcolm Pirnie, Inc. on the Lower Passaic River.
Discharge and runoff of water from non-point sources	• Data gap in water chemistry from non-point sources. • Partially characterized under the Contaminant Assessment Reduction Program.
Discharge of water from point sources	• Refer to Attachment 2 for known point source flow discharge • Data gap in water chemistry from point sources.
Exchange between porewater and water column	• Refer to Section 5.2.4 on groundwater interactions. • Data gap for porewater conditions.
Exchange between groundwater and water column	• Refer to Section 5.2.4 on groundwater interactions. • Data gap for porewater conditions.
Atmospheric dry and wet deposition and volatilization	• Limited atmospheric data available for the region • Limited data on dissolved-phase concentration needed to estimate loss by theory.

As noted in Table 5-1 and Table 5-2, a number of data gaps exist, which hinder the potential estimation of source areas in each river section. With the available data, the following evaluations and discussions are presented on potential source areas and contaminated media, including sediment, mudflats, water column, and groundwater.

5.2.1 SEDIMENT: POTENTIAL SOURCE AREA AND CONTAMINATED MEDIA

Surface sediment concentrations were evaluated and discussed in Section 4.4 "Surface Sediment Concentration" and Section 4.5 "Source Analysis" of the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c). The results of these evaluations are summarized below:

- Radar graphs depicting metals concentrations in surficial sediment reveal a consistent mass fraction pattern between RM0.9 and RM7. Similar radar graphs were generated for data collected above the Dundee Dam. These observations suggest that the source area of metals contamination is upriver of RM7 and may originate upriver of the Dundee Dam. In addition, metals concentrations in RM0.9 to RM7 (representing bank-to-bank samples) are relatively homogeneous, suggesting that tidal mixing serves to blend in any potential local source areas.
- The Upper Passaic River may be a source area of cadmium, lead, mercury, Total PCB, and Total DDT to the Lower Passaic River. However, additional source areas are likely present on the Lower Passaic River, contributing further additional load of these contaminants. The Upper Passaic River is likely *not* the source area of 2,3,7,8-TCDD to the Lower Passaic River with concentrations in the Upper Passaic River approximately 40 times less than concentrations in the Lower Passaic River.

The surface sediment concentration graphics presented in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) have been updated for this CSM with 2005 field data collected by Malcolm Pirnie, Inc. and TSI. These field data include the 2005 high resolution sediment cores collected in the Lower Passaic River and the 2005 low resolution sediment cores collected in Newark Bay.[17] Figure 5-3 presents the updated graphics with surface sediment concentrations for cadmium, copper, lead, mercury, Total PCB, and 2,3,7,8-TCDD. (The graph for Total DDT has not been updated for the CSM due to analytical problems in the 2005 field data related to matrix

[17] The Malcolm Pirnie, Inc. 2006 low resolution cores collected on the Lower Passaic River were not incorporated into Table 5-3 because the top of the core was not finely sliced, resulting in a lack of temporal resolution.

interference and low surrogate recovery.) Table 5-3 provides statistics on these surficial sediment concentrations. Note that validation of the 2005 Malcolm Pirnie, Inc. field data was not completed at the time that the CSM was updated. Nevertheless, unvalidated data are presented in Table 5-3 and Figure 5-3 to allow for a preliminary evaluation of surface concentration in the Lower Passaic River in 2005.

Table 5-3: Summary of Surficial Sediment Concentration from Dundee Dam to Newark Bay

Analyte	Newark Bay 2005 [a,b]	Lower Passaic River 1995 [a,c]	Lower Passaic River 2005 [a,d]	Dundee Dam 1985-1986 [a,e]
Cadmium (mg/kg)	0.92 ±0.56 (N = 23)	5.1 ±3.1 (N = 95)	4.9 ±3.1 (N = 6)	4.2
Copper (mg/kg)	98 ±24 (N =21)	230 ±250 (N = 95)	170 ±54 (N = 6)	120
Lead (mg/kg)	92 ±23 (N = 23)	330 ±150 (N = 90)	270 ±140 (N = 6)	307
Mercury (mg/kg)	1.5 ±0.69 (N = 23)	3.3 ±1.9 (N = 92)	2.6 ±2.1 (N = 6)	1.8
2,3,7,8-TCDD (μg/kg)	0.053 ±0.029 (N = 23)	0.81 ±2.0 (N = 95)	0.86 ±0.95 (N = 6)	0.02
Total PCB (μg/kg)[f]	410 ±140 (N = 21)	1,300 ±1,800 (N = 90)	580 ±730 (N = 6)	480

a: Arithmetic average and standard deviation (± 1 sigma) based on a normal distribution with sample size (N); nondetected values are incorporated into the average as half the reported detection limit
b: The 2005 TSI Newark Bay dataset represents surficial sediment (0-0.5 foot) from depositional locations.
c: The 1995 TSI Passaic dataset represents surficial sediment (0 to 0.5 foot) collected from depositional and non-depositional sampling locations.
d: The 2005 Malcolm Pirnie, Inc. Passaic dataset represents surficial sediment dating from 2003-2005. Validation process not complete for this dataset.
e: Literature data
f: Total PCB for the 2005 Newark Bay data and the 2005 Lower Passaic River data were calculated as the sum of congeners, (144 congeners and 159 congeners, respectively). The 1995 Lower Passaic River data and the Dundee Dam represent the sum of Aroclors.

The 2005 field data provide further insight to the processes on the Lower Passaic River since data are available at RM11 and RM12.6 and in Newark Bay. For the metals and Total PCB, the average 2005 surficial sediment concentrations at RM11 and RM12.6 are comparable to their respective concentrations at RM1.4 and RM2.2. In addition, the average 2005 surface concentrations for these analytes are also comparable to solids collected above the Dundee Dam, suggesting that the Upper Passaic River is contributing a significant portion of the load for specific contaminants on the Lower Passaic River. Local source areas on the Lower Passaic River may also contribute to the contaminant load, resulting in higher surface concentrations at the mouth of the river. Meanwhile, a distinct concentration gradient exists out the mouth of the Lower Passaic River and into Newark Bay in 2005, suggesting that Newark Bay is not contributing a contaminant load to the Lower Passaic River.

Conversely, 2,3,7,8-TCDD concentrations and the ratio of 2,3,7,8-TCDD/Total TCDD are fairly uniform along the Lower Passaic River, but these contaminants do not have an upriver source area. This observation suggests that tidal mixing along the length of the Lower Passaic River may impact sediment quality at RM11 and RM12.6. Salinity data presented in Section 2.2.1 "Evaluation of Salinity Data" defines the Transitional River Sections between RM6 and RM10+, and these salinity data indicate that the upriver extent of the salt wedge seasonally extends beyond RM10 into the Freshwater River Section. Moreover, this excursion needs to be frequent in order to produce the geochronological profiles observed at RM11 (Figure 5-4a)[18].

Over the past 75 years, the 2,3,7,8-TCDD concentrations from all three sediment cores (RM1.4, RM2.2, and RM11) are comparable, with low levels present in the 1920s (<0.001 µg/kg) and increasing to peak concentration in the 1960s (10 µg/kg) and then steadily declining to the present 2005 concentration (0.4 µg/kg). This concentration decline is likely due to reduced contaminant input and mixing of less contaminated solids in the surface sediment. Note that the peak concentration in the core collected at RM11 is less pronounced than the peak concentrations of the other two cores, suggesting that tidal mixing may have diluted the signal slightly. A similar plot showing the ratio of 2,3,7,8-TCDD / Total TCDD is provided in Figure 5-4b. Here, the diagnostic ratio of the Lower Passaic River (0.7 ±0.1; Malcolm Pirnie, Inc., 2006c and Chaky, 2003) is observed in all three cores from the 1960s to 2005. Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative Note that prior to the 1960s, the diagnostic ratio in the cores collected at RM1.4 and RM2.2 declines to a signature typical

[18] Downcore profiles presented in Figure 5-4 were constructed with unvalidated data collected during the Malcolm Pirnie, Inc. 2005 field program.

of atmospheric deposition and sewage discharge (Chaky, 2003) whereas the core collected at RM11 shows a distinctly different signature, which requires further evaluation.

If the upriver extent of the salt wedge seasonally extends upriver of RM10 and deposits fine-grained sediments in the Freshwater River Section, then fine-grained sediment deposits likely possess to some extent a contaminant inventory. Approximately 56 acres of the surficial sediment from RM10 to RM16.5 are classified as silt and silt/fine sand (as interpreted by Aqua Survey, Inc., 2006). This fine-grained sediment area accounts for 27 percent of the total area between RM10 to RM16.5, which is mainly comprised of coarse-grained sediment. If a mass per unit area (MPA) value is calculated for the sediment core at RM11 and applied to this fine-grained sediment area, then a contaminant inventory can be estimated. It is anticipated that the Freshwater River Section will harbor a smaller inventory of sediment-bound contaminants than the Transitional and Brackish River Sections due to the difference in sediment bed thickness. For example, the 2,3,7,8-TCDD inventory for RM10 to RM16.5 is estimated at 2 kg compared to the 29 kg reported for RM0.9 to RM7 (Malcolm Pirnie, Inc., 2006c), and the mercury inventory for RM10 to RM16.5 is estimated at 1.9 g compared to the 37 g reported for RM0.9 to RM7 (Malcolm Pirnie, Inc., 2006c).

Another observation from the surface concentration graphics (Figure 5-3) relates to the elevated contaminant levels observed at RM3.5. This observation is consistent with prior discussion in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) and the sedimentation rate discussion in Section 4.2 "Erosional and Depositional Areas." These discussions suggest the presence of an erosional area between RM3 and RM5 that is exposing older, more contaminated sediment, which is becoming distributed in the river by tidal mixing. Moreover, elevated concentrations of metals observed throughout the core collected at RM3.5 suggest that the sampling location was impacted by other source areas, erosional processes, or historical dredging activities.

The last observation from Figure 5-3 is the consistent downward contaminant concentration gradient that exists through the mouth of the Lower Passaic River and into Newark Bay. For most of the examined contaminants (organic and inorganic), concentrations drop approximately by a factor of 1.4 to 5 with 2,3,7,8-TCDD concentration dropping by a factor of 16. Refer to Table 5-4 for a summary.

Table 5-4: Concentration Decrease between Lower Passaic River and Newark Bay Concentrations (2005)

Analyte	Factor Decrease in 2005
Cadmium	5.3
Copper	1.7
Lead	2.9
Mercury	1.7
2,3,7,8-TCDD	16
Total PCB	1.4

5.2.2 Shoals: Potential Source Area and Contaminated Media

The "shoals" are defined as areas located outside the footprint of the authorized dimensions of the federal navigation channel. Within the shoals, some areas, known as tidal mudflats, may be periodically exposed and inundated during the tidal cycle. During these periodic tidal cycles, solids are exchanged through resuspension and deposition processes. As further discussed in Section 5.2 "MPA Approach" of the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c), the average depth of contamination in the sediments (which was estimated using historical mercury data) is approximately 9 feet (sample size 116 cores). This average depth incorporates sediment cores collected in the channel and on the shoals of the Lower Passaic River and includes historical cores that showed incomplete concentration profiles.[19] It is anticipated that the average depth of contamination may actually be deeper than 9 feet since 48 percent of the historical mercury cores were incomplete with a rising concentration gradient at the bottom of the core. Moreover, it is anticipated that since sediments are longitudinally

[19] An incomplete sediment core profile is defined as a core where the concentration in the bottom segment is not equal to background concentrations, or post-industrial conditions. Hence, the contaminant inventory at that sampling location is uncertain. Incomplete sediment cores result from the presence of dredge horizons or cores that do not penetrate deep enough into the sediment bed.

well-mixed by the river, sediment beds in the channel and on the shoals are both likely contaminated.

To further investigate the potential depth of contamination in the shoals, cores (historical low resolution cores) located outside the authorized federal navigation channel were separated based on their geographical coordinates. Downcore profiles of mercury were then constructed for these selected shoal cores (sample size 59 cores).[20] Of the 59 shoal cores identified, approximately half showed complete mercury concentration profiles, thus the depth of contamination is known. For the complete cores, the average depth of contamination in the shoals is approximately 7 feet (minimum depth of 0.1 foot and maximum depth of 19 feet). Conversely, the other half of the cores showed incomplete mercury concentration profiles; therefore, the depth of contamination is unknown but is greater than the depth of the core bottom. For these incomplete cores, the bottom of the collected core was 7 feet on average (suggesting that the depth of contamination is greater than 7 feet at these incomplete coring locations).

The current CSM for the Study does not account for the apparent deep contamination in the shoals. Anthropogenic activities and the longitudinally well-mixed nature of the river (described above) very likely contributed to shoal contamination. Possible anthropogenic activities may include: filling in historical wetlands and marshes along the river banks (Iannuzzi *et al.*, 2002), hardening of the shorelines, dredging areas outside the authorized dimensions of the federal navigation channel (for example for a shipping berth), or dredging activities that altered the natural course of the river.

5.2.3 Water Column: Potential Source Area and Contaminated Media

The discussion of the water column as a potential source area is particularly limited by the lack of available water chemistry data. In 2005, Malcolm Pirnie, Inc. deployed semi-permeable membrane devices and collected small-volume and large-volume water column samples along the main stem of the Lower Passaic River and at the confluences

[20] Mercury was selected as a surrogate to identify depth of contamination because mercury contamination occurs deeper in the sediment bed relative to 2,3,7,8-TCDD and Total PCB (Malcolm Pirnie, Inc., 2006a).

of the major tributaries; however, a complete evaluation of the data has not been completed. Historical water chemistry data were discussed in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) and are summarized below. [Refer to Section 4.7 "Water Column and Biota Evaluations," Appendix C, and Appendix D of the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) for more information.]

- Surface sediments (0-0.5 foot) from RM0.9 to RM7 are homogeneous, which likely resulted from tidal mixing and the resuspension of solids. For mercury, lead, polycyclic aromatic hydrocarbons (Total PAH), Total PCB, and Total DDT, the suspended-phase concentrations approximate the surficial sediment concentrations (0-0.1 cm) implying that resuspension is likely influencing sediment homogeneity.
- Once resuspended in the water column, solids may impact water quality due to the partitioning of chemicals from the sorbed phase to the dissolved phase.. In general, the suspended solids were more contaminated than the dissolved-phase.
- The ratio of 2,3,7,8-TCDD/Total TCDD for surface sediment in the Lower Passaic River was reported as 0.7 ±0.1 [refer to the *Preliminary Geochemical Evaluation*; Attachment B in the Work Plan (Malcolm Pirnie, Inc., 2005a)]. If surface sediments are being resuspended and analytes are distributing to the water column, then it is anticipated that water quality and potentially biota will reflect a similar 0.7 ratio for 2,3,7,8-TCDD/Total TCDD. Indeed, suspended-phase and dissolved-phase constituents have a 2,3,7,8-TCDD/Total TCDD ratio of approximately 0.5 to 0.8 while blue crab tissue had a ratio of approximately 0.6 to 0.9.

5.2.4 GROUNDWATER: POTENTIAL SOURCE AREA AND CONTAMINATED MEDIA

Groundwater hypothetically represents another potential source area to the Lower Passaic River. This medium can potentially impact a water body's water quality in two ways: (1) by carrying contaminants from nearby groundwater contamination sites to the river and (2) by mobilizing contaminant particles trapped in the river sediment and allowing them to enter the river water column. In addition, some studies have shown that low molecular weight, more hydrophilic chemicals (such as organic solvents) can mobilize heavier compounds having high soil-water partition coefficients (Huling, 1989). Consequently, a screening analysis[21] is appropriate to evaluate the potential for groundwater to contribute to the mobilization of contaminants in the river.

To assess the groundwater's potential to contribute contaminant loads to the Lower Passaic River, a simple, conservative, qualitative assessment of groundwater entering the river system was completed (refer to Attachment 2 for a complete discussion on groundwater). Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

[21] To date, analyses of groundwater samples from adjacent to, or beneath the Lower Passaic River, have not been performed to assess the potential impact.

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

5.3 INITIAL MASS BALANCE FOR THE LOWER PASSAIC RIVER AND NEWARK BAY

An initial mass balance for the Lower Passaic River and Newark Bay was documented in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c). In this initial mass balance, contributions from tributaries, non-point sources, point sources, and floodplains were removed because data gaps exist on the solids load from each of these source areas and the corresponding sediment chemistry. Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative Three observations suggest that Newark Bay sediments are not being transported into the Lower Passaic River on any significant scale and that, for most contaminants, transport upriver from Newark Bay is even less important:

- The intensity of the downward concentration gradients at the mouth of the Passaic River.
- The homogeneity of the contaminant concentrations within the Lower Passaic River (RM0.9 to RM7).

- The similarity of Upper Passaic River sediment concentrations to those concentrations in the Lower Passaic River.

Instead, Passaic-contaminated sediments are likely being transported out to Newark Bay and impacting Newark Bay sediment quality. These concepts are summarized in the following subsections.

5.3.1 NEWARK BAY 2,3,7,8-TCDD MASS BALANCE

To constrain the mass balance calculations for Newark Bay, both 2,3,7,8-TCDD and Total TCDD were balanced simultaneously. Then, a separate mass balance was completed for mercury. Because the ratio of 2,3,7,8-TCDD and Total TCDD is well known throughout the Newark Bay area and their geochemistries are similar, they provide essentially conservative tracers of solids in the Newark Bay area. Fitting a mass balance to them provides a powerful constraint on the mass balance calculations since loads of both contaminants must be matched with the same set of solids inputs.

The mass balance results for 2,3,7,8-TCDD and Total TCDD are presented in Table 5-5 [excerpt from the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c)]. The annual load of 2,3,7,8-TCDD (units of gram/year) was calculated from the measured concentration of 2,3,7,8-TCDD in each waterbody multiplied by the revised solids mass balance [refer to Section 4.6 "Chemical Mass Balance" in the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c)]. The total mass of 2,3,7,8-TCDD entering Newark Bay is approximately 14 g/year, resulting in a calculated Newark Bay sediment concentration for 2,3,7,8-TCDD of 0.083 μg/kg (annual load divided by solids load). Since this calculated concentration approximates the measured 2,3,7,8-TCDD concentration, no other major sources of 2,3,7,8-TCDD are present, and the chemical mass balance is considered closed. Similarly for Total TCDD, the mass balance appears closed since the estimated surface concentration matches the measured concentration in Newark Bay. The balance is further verified by the estimated ratio of 2,3,7,8-TCDD/Total TCDD, which also matches the measured data.

Table 5-5: 2,3,7,8-TCDD Mass Balance for Newark Bay

Source Area [a]	Solids Mass Balance [b]		2,3,7,8-TCDD Concentration	2,3,7,8-TCDD Annual Load	Total TCDD Concentration	Total TCDD Annual Load	Ratio of 2,3,7,8-TCDD to Total TCDD
	cubic yard/year	Metric-ton/year	(µg/kg) [c]	(g/year)	(µg/kg) [c]	(g/year)	(unitless)
Passaic River (RM0.9 to RM7)	35,600	21,200	0.54	12	0.68	14	0.8
Mouth of Hackensack River	6,460	3,870	0.093	0.36	0.14	0.54	0.67
CSO/WWTP [d]	10,500	6,300	UK [e]	UK	UK	UK	UK
Atmospheric Deposition	285	170	UK	UK	UK	UK	UK
Kill van Kull	241,000	116,000	0.01 [f]	1.16	0.07	7.7	0.15
Arthur Kill	49,300	23,700	0.05	1.19	0.18	4.2	0.28
Total	343,000	171,000		14		26	
Newark Bay Calculated			**0.083**		**0.15**		**0.53**
Newark Bay Measured			**0.076**		**0.16**		**0.56**
Total Annual Load	**343,000 cubic yard/year**			**14 g/year**		**26 g/year**	

a: Excerpt from *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c).
b: Solids mass balance based on Lowe, *et al.* (2005) with several adjustments made to satisfy the chemical mass balance. Conversion of sediment volume to sediment mass as given by Lowe, *et al* (2005).
c: Concentrations represent average surface sediment concentrations for 1991 to 1995 sediments, unless otherwise noted.
d: CSO = Combined sewer overflow; WWTP = Wastewater treatment plant
e: UK = unknown value. Mass fluxes for source areas within unknown values were set to zero for the chemical mass balance.
f. Concentration represents mean New York harbor sediments at the entry to Kill van Kull 1994-1998 (Chaky, 2003).

5.3.2 NEWARK BAY MERCURY MASS BALANCE

Unlike the 2,3,7,8-TCDD and Total TCDD mass balances, the mercury mass balance required an additional, substantive mercury input to complete the balance [Table 5-6; excerpt from the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c)]. The total mass of mercury entering Newark Bay from known source areas is 259,000 g/year. This annual load yields a calculated Newark Bay sediment concentration for mercury of 1.5 mg/kg (annual load divided by solids load). The concentration is much less than the measured mercury concentration in Newark Bay of 2.4 mg/kg, implying that another mercury input is impacting Newark Bay. To complete the mercury mass balance, additional source area(s) producing 150,000 g/year is required to generate a calculated Newark Bay sediment concentration of 2.4 mg/kg. Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Note that this calculation assumes that the additional input of mercury does not contribute any substantive solids to the system (Malcolm Pirnie, Inc., 2006c).

Table 5-6: Mercury Mass Balance for Newark Bay

Source Area [a]	**Solids Mass Balance** [b]		**Mercury Concentration**	**Mercury Annual Load**
	Cubic yard/year	**Metric-ton/year**	**(mg/kg)** [c]	**(g/year)**
Passaic River (RM0.9 to RM7)	35,600	21,200	3.4	73,000
Mouth of Hackensack River	6,460	3,870	4.0	16,000
CSO/WWTP [d]	10,500	6,300	UK [e]	UK
Atmospheric Deposition	285	170	UK	UK
Kill van Kull	241,000	116,000	1.1	132,000
Arthur Kill	49,300	23,700	1.6	38,000
Total	343,000	171,000		259,000
Newark Bay Calculated			**1.5**	
Missing Mercury Input				150,000
New Newark Bay Calculated			**2.4**	
Newark Bay Measured			**2.4**	
Net Annual Load				**409,000 g/year**

a: Excerpt from *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c).
b: Solids mass balance based on Lowe, *et al*. (2005) with several adjustments made to satisfy the chemical mass balance. Conversion of sediment volume to sediment mass as given by Lowe, *et al.*, 2005.
c: Mercury concentrations represent average surface sediment concentrations for 1991 to 1995 sediments.
d: CSO = Combined sewer overflow; WWTP = Wastewater treatment plant
e: UK = unknown value. Mass fluxes for source areas within unknown values were set to zero for the chemical mass balance.

6.0 CONTAMINANT FATE AND TRANSPORT

The initial CSM (Malcolm Pirnie, Inc., 2005a) provided a preliminary fate and transport model for the Lower Passaic River (Figure 6-1 and Figure 6-2). This preliminary model depicts the movement of chemicals between the sediment, water column, and air through a series of reactions and pathways to achieve equilibrium. Certain bioavailable, hydrophobic chemicals will also partition from either the sediment or water column into biological tissue. Depending on the chemical nature of these bioavailable chemicals, they may bioaccumulate in the food web, resulting in higher tissue concentrations in higher trophic level receptors.

The abiotic reactions and pathways are presented in Figure 6-1 as black arrows; additional biological pathways are added to this underlying graphic as green arrows and presented in Figure 6-2. [For a complete discussion of biological pathways, refer to the *Pathways Analysis Report* (Battelle, 2005).] The chemical state (*i.e.*, sorbed chemical, dissolved chemical, or vapor) is denoted in the boxes, which represent inventory while mechanisms are represented by arrows connecting associated boxes, as appropriate. Both figures portray general reactions and pathways that may occur in the Transitional River Section. However, some reactions and pathways may be absent or less significant for certain chemicals and for certain river sections. Potential mechanisms influencing fate and transport of a given chemical in the water and air include advection, flocculation (aggregation) or disaggregation, sorption or desorption, degradation, volatilization, and/or deposition. In the sediment, the potential mechanisms include sorption or desorption, resuspension, degradation, potential burial or bioturbation, and transformations. In biota, the potential mechanisms are bioconcentration and bioaccumulation.

6.1 NATURE AND EXTENT OF CONTAMINATION

The *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) discusses the nature and extent of contamination for several contaminants in the Lower Passaic River. General geochemical observations include:

- The high degree of spatial homogeneity exhibited in the coring data (RM0.9 to RM7) suggests that localized areas of relatively higher concentrations typically described as "hot spots" do not exist in the Lower Passaic River. Instead, "hot regions" of the river typically exist on the scale of a mile or more, nearly bank to bank in lateral extent.
- Dated sediment cores from the Upper Passaic River and Lower Passaic River were used to differentiate the source media for several major contaminants. These cores suggest that the major historical loads of cadmium, lead, mercury, and Total PCB originated in the Upper Passaic River above the Dundee Dam. A substantial load of copper also originated above the Dundee Dam, but an additional load was also present downriver. Smaller contaminant source areas, particularly mercury, may also have existed in the Lower Passaic River (RM0.9 to 7.0).
- Surface sediment data in the RM3.5 to 4 region had a relatively high density of elevated values, occurring across several contaminants, suggesting that this region may have a number of locations undergoing erosion and exposing older, more contaminated sediments. The consistent occurrence of these elevated values across several contaminant types tends to rule out the possibility of an ongoing local source area since it would need to include the major contaminants.

In the following section, chemical-specific (mercury, lead, 2,3,7,8-TCDD, Total PCB, and Total DDT) discussions on the nature and extent of contamination are presented [refer to the *Draft Geochemical Evaluation (Step 2)* (Malcolm Pirnie, Inc., 2006c) for a complete discussion].

6.1.1 MERCURY NATURE AND EXTENT OF CONTAMINATION

Dated sediment cores from the Upper and Lower Passaic Rivers and an examination of metals ratios suggest that the major historical mercury loads primarily originated in the Upper Passaic River above the Dundee dam. An examination of the 1995 surface sediments in the Lower Passaic River suggests that at least two source areas for mercury were present in 1995: one at or below RM1 and one at or above RM7. Dated sediment cores show a similar condition for mercury in 1963. Dated sediment cores were insufficient to establish the depth of contamination for mercury, although peak concentrations appear to have occurred in the 1960s, concurrent with the 2,3,7,8-TCDD maximum.

Ratio analysis of metals contaminations in the Lower Passaic River (RM0.9 to RM7) showed little variation in the metals pattern. Analysis of surface metals concentrations also showed relatively little trend with river mile. This evidence demonstrates the homogeneity of contaminant concentrations in surficial sediments in the Lower Passaic River and suggests that tidal mixing is able to homogenize local metals loads over long distances, prior to the deposition of the contaminants in the river bottom (Malcolm Pirnie, Inc., 2006c).

6.1.2 LEAD NATURE AND EXTENT OF CONTAMINATION

Like mercury, major lead contamination in the Lower Passaic River likely occurred in the 1960s or earlier. Elevated concentrations of lead (approximately 700 mg/kg) occur at depth in dated sediment cores, usually reaching a maximum at the core bottom. This evidence indicates that the vertical extent of lead (as well as other metals, such as arsenic, chromium, copper, cadmium, and mercury) is undefined. Major inventories of lead and other metals most likely lie below the documented depth of 2,3,7,8-TCDD contamination. An examination of metals ratios in dated sediment cores and surface sediment samples further supports the origin of the Lower Passaic River lead contamination above the Dundee Dam (Malcolm Pirnie, Inc., 2006c).

6.1.3 2,3,7,8-TCDD NATURE AND EXTENT OF CONTAMINATION

Consistent with the observations by Bopp *et al.* (1991a) and Chaky (2003) for Newark Bay, dated sediment cores for the Lower Passaic River (RM0.9 to RM7) show that the major releases of 2,3,7,8-TCDD begin in the 1950s and peak in the early 1960s. Dated sediment cores from the Upper Passaic River and Lower Passaic River further indicate that much less than 1 percent of the 2,3,7,8-TCDD contamination in the Lower Passaic River originated above the Dundee Dam historically. The Upper Passaic River remains a trivial source of 2,3,7,8-TCDD to the Lower Passaic River despite the passage of time.

The diagnostic ratio of 2,3,7,8-TCDD/Total TCDD of 0.7 to 0.8 can be used to trace Lower Passaic River 2,3,7,8-TCDD (resulting from industrial contamination) throughout the Newark Bay complex and over the last 60 years. Based on dated sediment cores, this diagnostic ratio is observed throughout the sediments of the Lower Passaic River as far back as the 1950s. Prior to 1950, however, the 2,3,7,8-TCDD/Total TCDD ratio of less than 0.05 is characteristic of sewage and atmospheric fallout (Malcolm Pirnie, Inc., 2006c).

6.1.4 TOTAL PCB NATURE AND EXTENT OF CONTAMINATION

Total PCB contamination is distributed throughout the Lower Passaic River with peak concentration (4 to 18 mg/kg) occurring in the sediments dating to the 1960s. Aroclor 1248 is the most commonly reported PCB mixture, typically comprising 60 percent or more of the Total PCB burden. Dated sediment cores from the Upper Passaic River and Lower Passaic River suggest that the major historical loads of Total PCB primarily originated in the Upper Passaic River above the Dundee Dam. In 1963, the Total PCB input upriver of the Dundee Dam accounted for the majority of the Total PCB load in the Lower Passaic River. However, evidence suggests that currently (circa 1995), the Upper Passaic River Total PCB input has become less important relative to Lower Passaic River Total PCB load. Nevertheless, the Upper Passaic River source area may still comprise one third of the Total PCB loading in the Lower Passaic River. Evidence also suggests that in 1995 at least one source area exists in the Lower Passaic River for Total PCB (Malcolm Pirnie, Inc., 2006c).

6.1.5 TOTAL DDT NATURE AND EXTENT OF CONTAMINATION

Dated sediment cores reveal that Total DDT contamination in the Lower Passaic River began in the 1930s, peaking in the late 1940s or early 1950s, which is consistent with the observations of Bopp *et al.* (1991a). Results consistently show measurable Total DDT concentrations occurring deeper in the sediment core than measurable 2,3,7,8-TCDD concentrations. Dated sediment cores from the Upper Passaic River and Lower Passaic River further indicate that relatively little, perhaps one quarter the input, of the Total DDT contamination in the Lower Passaic River originated above the Dundee Dam (Malcolm Pirnie, Inc., 2006c).

6.2 ESTIMATED FUTURE SURFACE CONCENTRATIONS

At the time that this CSM was updated, two source areas had been identified for the Lower Passaic River: (1) contaminated solids originating above the Dundee Dam and being transported downriver and (2) erosional areas located below the dam that are eroding and exposing older, more contaminated sediments, which could in turn be transported throughout the river during tidal cycles. Based on the fate and transport processes discussed above, these known source areas (compounded by other unknown potential source areas) will likely continue to control the future surface sediment concentrations on the Lower Passaic River.

As part of the FFS, target areas were identified to satisfy the Remedial Action Objectives (refer to Appendix B "Target Area Analysis" of the FFS document). Remedial actions at one or more of these target areas will impact future surface sediment concentrations. These target areas are:

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

Ex. 5: predecisional and deliberative

7.0 FUTURE CSM UPDATES

7.1 UNCERTAINTIES IN THE CSM

The updated CSM does contain uncertainties due to the data gaps that exist regarding the contamination source areas on the Lower Passaic River; interactions between the sediments, water column, groundwater, and air; and transportation of chemicals through the system. For example, very limited field data exist for areas upriver of RM7 and downriver of RM1; water column and hydrodynamic data are incomplete for the entire stretch of the Lower Passaic River; and the interactions between Newark Bay and the Lower Passaic River are not completely understood. Other uncertainties involve the appropriate linkage of the human health and ecological exposure pathways and receptors (Battelle, 2005) to the geochemical CSM presented here to construct a comprehensive CSM.

To address current limitations of the CSM, data should continue to be collected in the future and evaluated to resolve uncertainties and associated data gaps. Moreover, as relevant data gaps are identified during the DQO process, a procedure is needed for maintaining, refining, and updating the CSM to understand site-specific conditions.

7.2 REFINE AND MAINTAIN THE CSM

To accomplish this CSM refinement, appropriate study questions, including risk hypotheses and questions aimed at evaluation of risk-based remediation, have been and should continue to be posed. Then, historical data should be evaluated and appropriate field data collected to address the study questions and to increase the understanding of the system. Due to the complexity of the Study, future iterations of the CSM may include separate models to highlight different aspects of the project. These individual models may focus on source areas, release and media, human health exposure pathways and receptors, and ecological exposure pathways and receptors.

The current CSM is designed to be refined and updated to address uncertainties associated with data gaps. An updated CSM can be combined with a refined chemical/biological fate and transport model for each benchmark chemical. These chemical-specific, fate and transport models may then be adjusted for each river section accounting for dominant sources or natural processes. An integration of the information presented in the *Pathways Analysis Report* (Battelle, 2005) would complete the exposure pathway from source to receptor.

8.0 ACRONYMS

cfs	Cubic Feet per Second
CSM	Conceptual Site Model
CSO	Combined sewer overflow
DDT	Dichlorodiphenyltrichloroethane
DQO	Data Quality Objective
FFS	Focused Feasibility Study
MPA	Mass Per Unit Area
NGVD29	National Geodetic Vertical Datum of 1929
NJPDES	New Jersey Pollution Discharge Elimination System
NRDA	Natural Resource Damage Assessment
OSWER	Office of Solid Waste and Emergency Response
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
QAPP	Quality Assurance Project Plan
R^2	Linear Regression Coefficient
RM	River Mile
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TSI	Tierra Solutions, Inc.
UK	Unknown (refer to acronyms in tables)
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WWTP	Wastewater treatment plant
‰	parts per thousand or "per mil"

9.0 REFERENCES

Aqua Survey, Inc., 2006. "Technical Report, Geophysical Survey, Lower Passaic River Restoration Project." Lower Passaic River Restoration Project. July 2006.

Battelle, 2006. "Pathways Analysis Report." Newark Bay Study. May 2006.

Battelle, 2005. "Pathways Analysis Report." Lower Passaic River Restoration Project. July 2005.

Bopp RF, Chillrud SN, Shuster EL, and Simpson HJ, 2006. "Contaminant Chronologies from Hudson River Sedimentary Records." In: The Hudson River Estuary, J. Levinton and J. Waldman eds., Cambridge University Press, January 2006, Chapter 26: 383-397.

Bopp RF, Gross ML, Tong H, Simpson HJ, Monson SJ, Deck BL, and Moster FC, 1991a. "A major incident of dioxin contamination: Sediments of New Jersey Estuaries." Environmental Science Technology. 25(5): 951-956.

Bopp RF Gross ML, Tong H, Simpson HJ, Monson SJ, Deck BL, and Moster FC, 1991b. "Sediment sampling and radionuclide and chlorinated hydrocarbon analysis in Newark Bay and the Hackensack and Passaic Rivers." Report to New Jersey Department of Environmental Protection, Division of Science and Research Contract P24096, March 31, 1991.

Chaky DA, 2003. "Polychlorinated Biphenyls, Polychlorinated Dibenzo-p-Dioxins and Furans in the New York Metropolitan Area; Interpreting Atmospheric Deposition and Sediment Chronologies." PhD Thesis, Rensselaer Polytechnic Institute, Troy, NY. August 2003.

Earth Tech, Inc. and Malcolm Pirnie, Inc., 2006. "Draft Final Restoration Opportunities Report." Lower Passaic River Restoration Project. July 2006.

Earth Tech, Inc. and Malcolm Pirnie, Inc., 2005. "Report for December 14, 2004 to February 24, 2005 Field Reconnaissance." Lower Passaic River Restoration Project. February 2005.

Germano & Associates, Inc., 2005. "Final Report: Sediment Profile Imaging Survey of Sediment and Benthic Habitat Characteristics of the Lower Passaic River." Prepared for Aqua Survey, Inc. August 2005.

Huling SG, 1989. "Facilitated Transport: EPA Superfund Groundwater Issue." August 1989. http://www.epa.gov/ada/download/issue/facili.pdf.

Iannuzzi T, Ludwig DF, Kinnell JC, Wallin JM, Desvousges WH, and Dunford RW. 2002. A Common Tragedy: History of an Urban River. Amherst Scientific Publishers. (Amherst, Massachusetts).

Lowe S, Abood K, Ko J, and Wakeman T, (in press). "A sediment budget analysis of Newark Bay." Journal of Marine Science and Environment. 2005.

Malcolm Pirnie, Inc., 2006a. "Community Involvement Plan." Lower Passaic River Restoration Project and Newark Bay Study. June 2006.

Malcolm Pirnie, Inc., 2006b. "Draft Field Sampling Plan (Volume 2)." Lower Passaic River Restoration Project. Prepared in conjunction with Earth Tech, Inc. and Battelle. June 2006.

Malcolm Pirnie, Inc., 2006c. "Draft Geochemical Evaluation (Step 2)." Lower Passaic River Restoration Project. Prepared in conjunction with Battelle and HydroQual, Inc. March 2006.

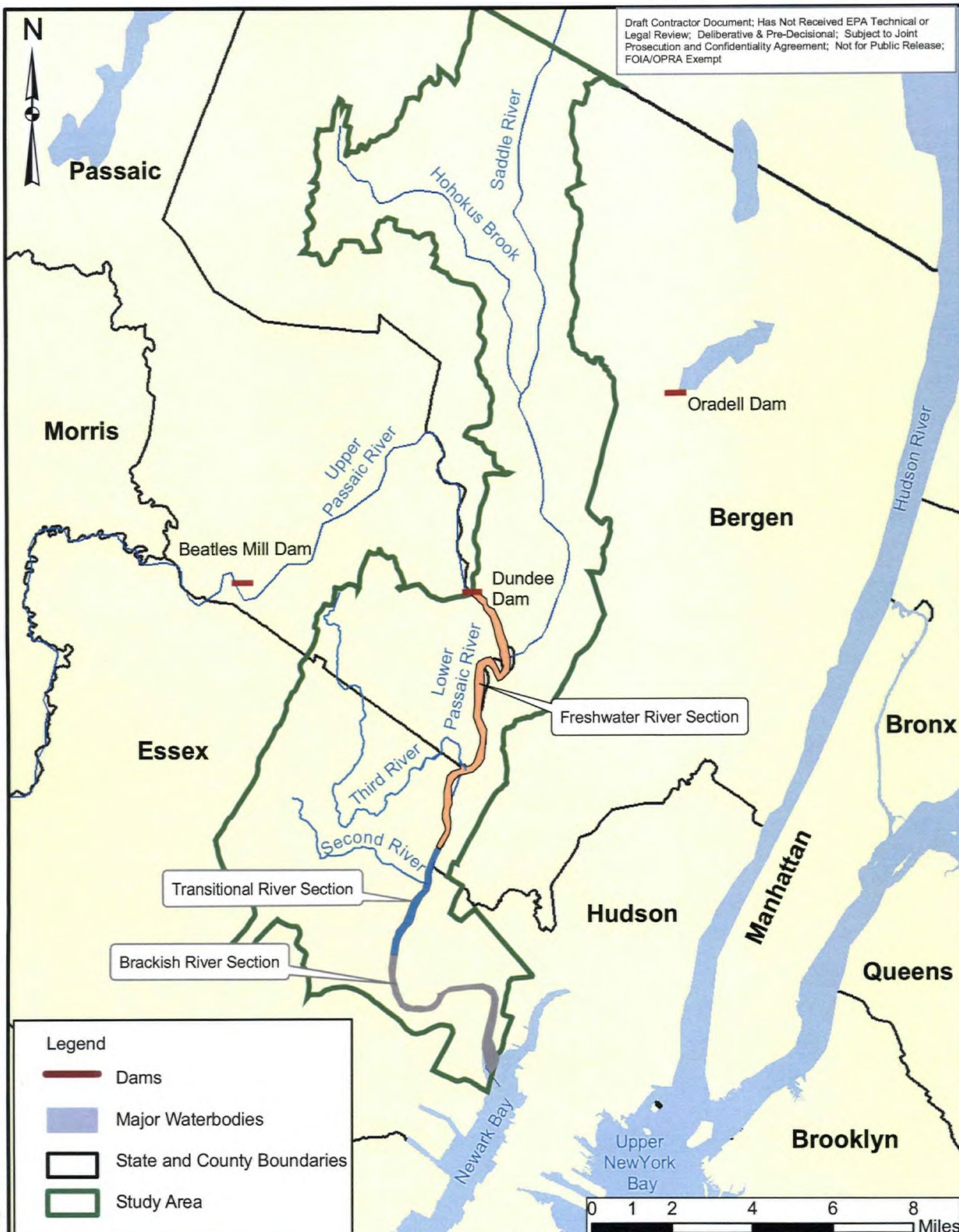
Malcolm Pirnie, Inc., 2005a. "Work Plan." Lower Passaic River Restoration Project. Prepared in conjunction with Battelle and HydroQual, Inc. August 2005.

Malcolm Pirnie, Inc., 2005b. "Quality Assurance Project Planning." Lower Passaic River Restoration Project. Prepared in conjunction with Battelle and HydroQual, Inc. August 2005.

Olsen, CR, Larsen IL, Brewster RL, Cutshall NH, Bopp RF, and Simpson H, 1984. "A geochemical assessment of sedimentation and contaminant distributions in the Hudson-Raritan Estuary." NOAA, NOS OMS 2. June 1984.

USEPA, 2000. "Data Quality Objective Process for Hazardous Waste Site Investigation." Office of Environmental Information. EPA/600/R-00/007. January 2000 (Washington, DC).

USEPA, 1988. "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA." Office of Emergency and Remedial Response. OSWER Directive 9355.3-01. EPA/540/G-89/004. October 1988. (Washington, DC).



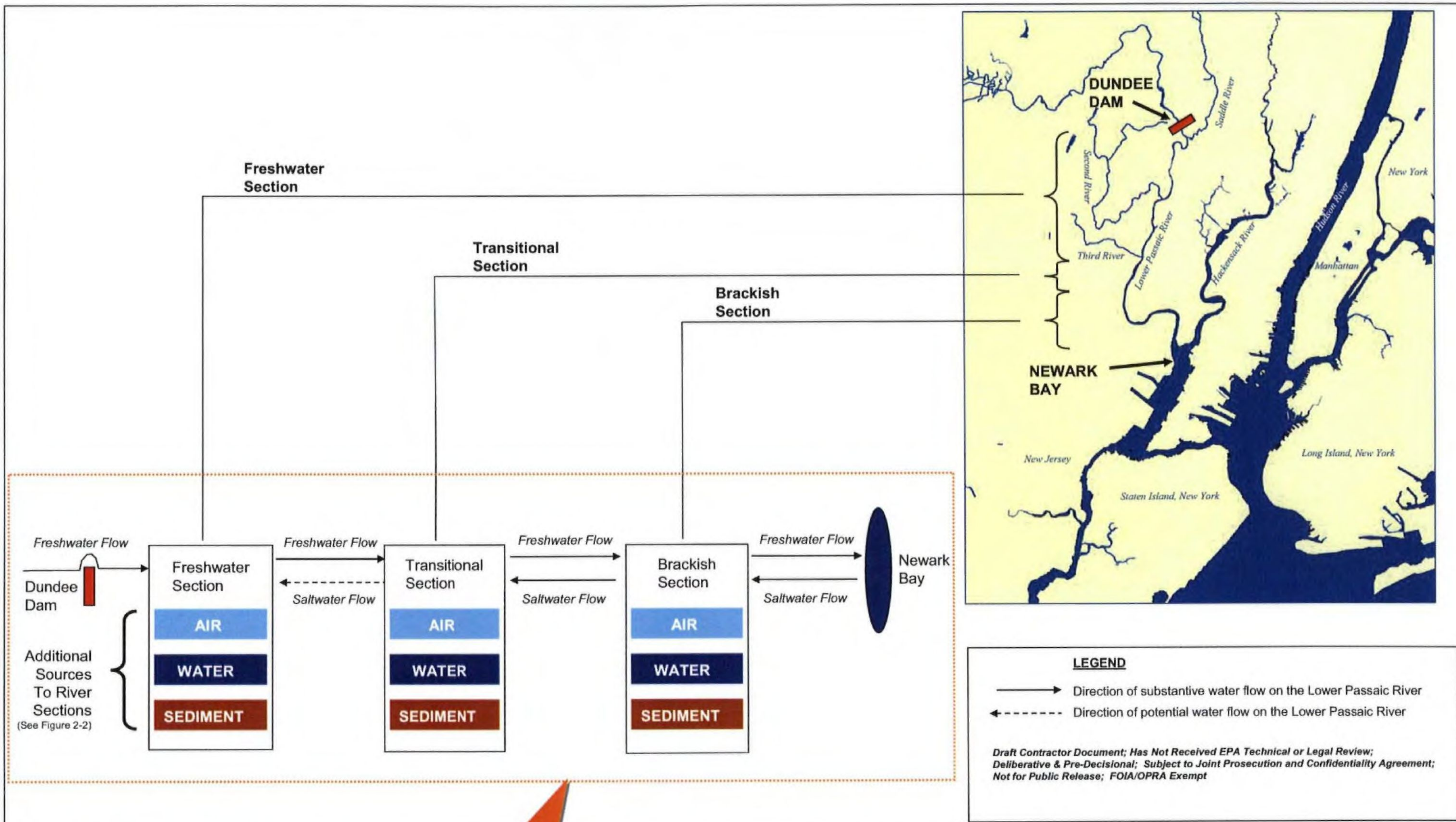
Study Area Location Map

Lower Passaic River Restoration Project

FIGURE 1-1

September 2006
Pre-Draft

Map Document: (S:\Projects\PASSAIC\MapDocuments\4622001-WRDA\MXD\FSP2_033106\MXDS\introduction\sitelocation.mxd)
5/10/2006 -- 5:55:27 PM



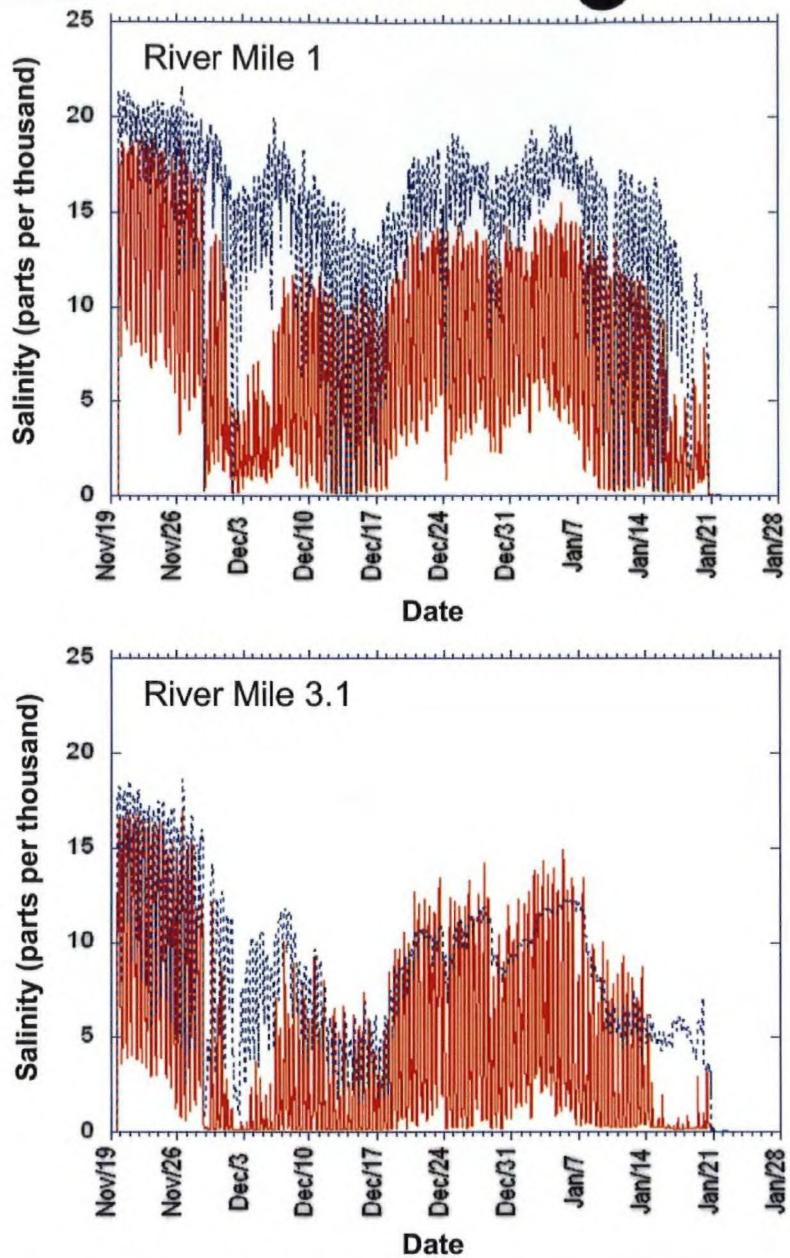
US Army Corp of Engineers

River Sections for the Lower Passaic River

Figure 2-1

Lower Passaic River Restoration Project

September 2006
Pre-Draft



Legend

Salinity measurements collected by Rutgers University near the water surface (solid red line)

Salinity measurements collected by Rutgers University near the water bottom (dashed blue line)

Notes

Measurements were collected between November 20, 2004 and January 25, 2005 by Rutgers University.

River Mile 1 – Data collected from Rutgers University Buoy #M1.

River Mile 3.1 – Data collected from Rutgers University Buoy #M2a.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

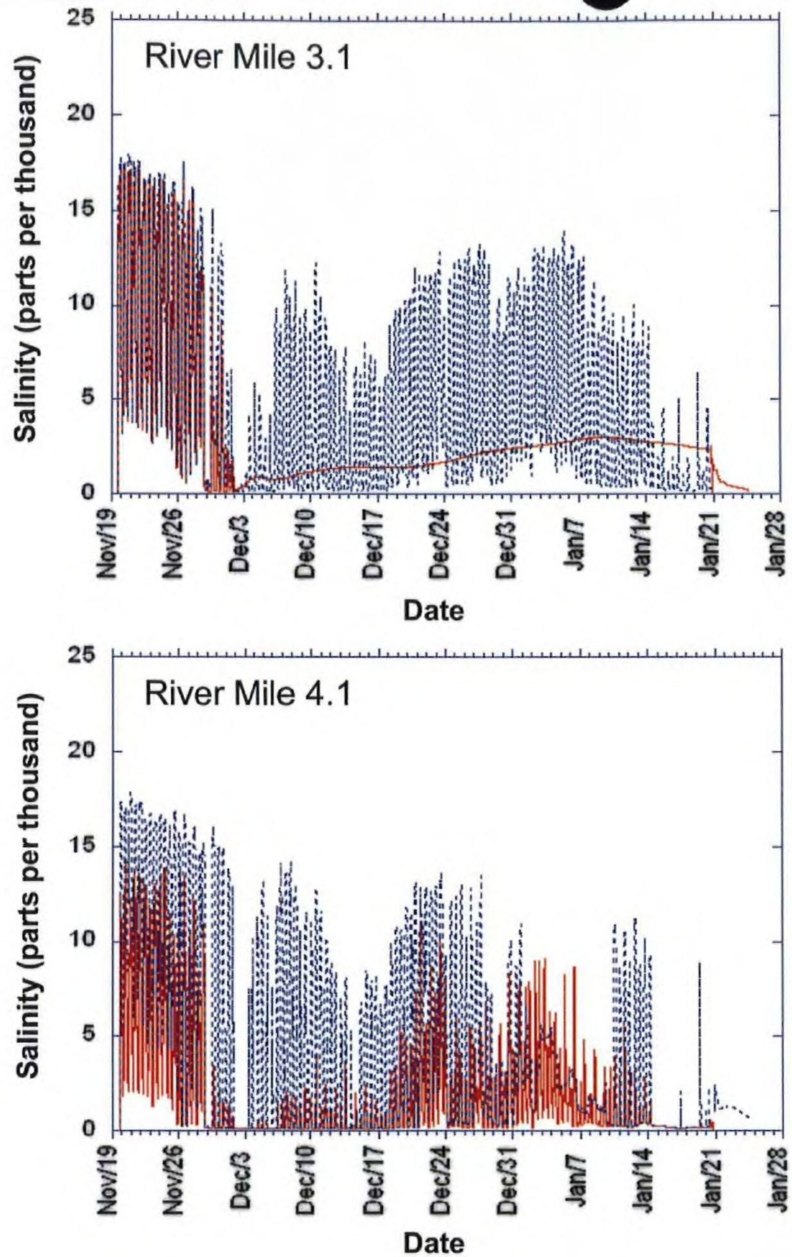
Source for Rutgers University data: http://marine.rutgers.edu/cool/passaic

Temporal Trends in Salinity at River Miles 1 and 3.1

Lower Passaic River Restoration Project

Figure 2-2a

September 2006
Pre-Draft



Legend

Salinity measurements collected by Rutgers University near the water surface

Salinity measurements collected by Rutgers University near the water bottom

Notes

Measurements were collected between November 20, 2004 and January 25, 2005 by Rutgers University.

River Mile 3.1 – Data collected from Rutgers University Buoy #M2b, which was located next to Buoy #M2a.

River Mile 4.1 – Data collected from Rutgers University Buoy #M3.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

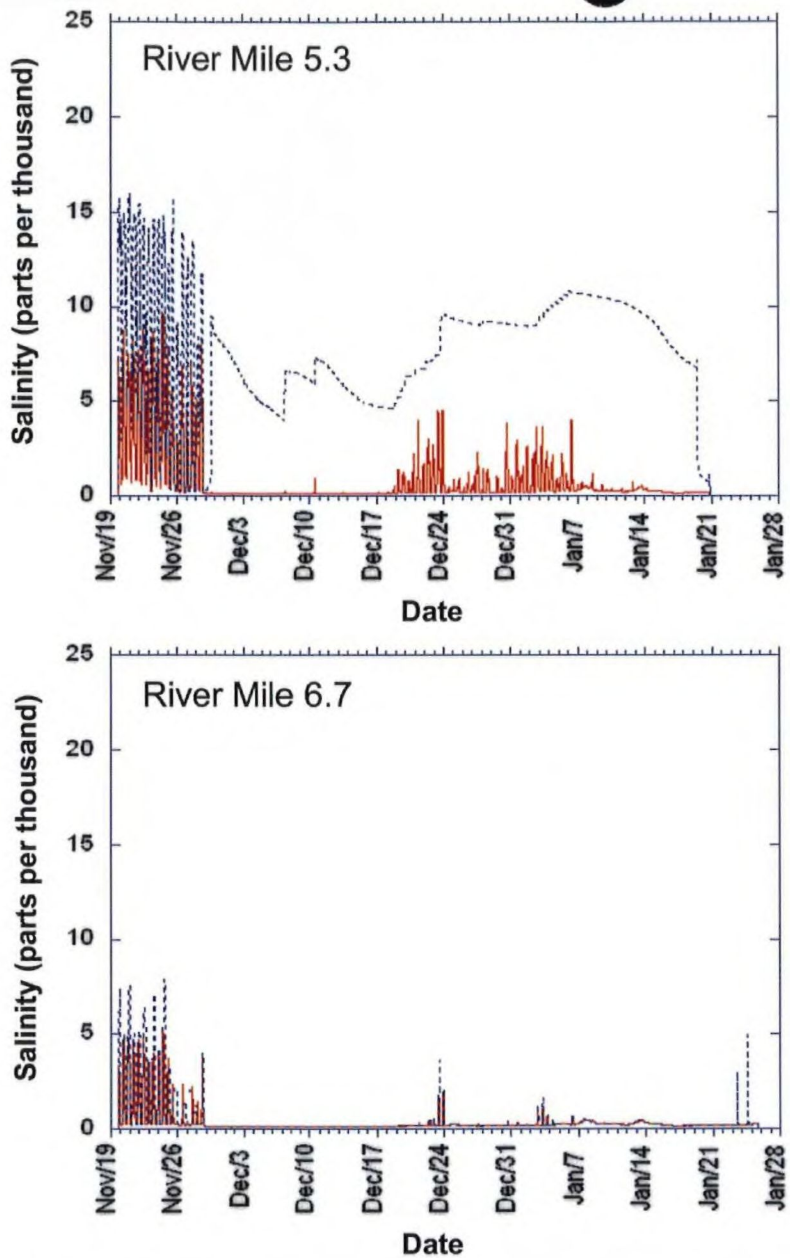
Source for Rutgers University data: http://marine.rutgers.edu/cool/passaic

Temporal Trends in Salinity at River Miles 3.1 and 4.1

Lower Passaic River Restoration Project

Figure 2-2b

September 2006
Pre-Draft



Legend

Salinity measurements collected by Rutgers University near the water surface

Salinity measurements collected by Rutgers University near the water bottom

Notes

Measurements were collected between November 20, 2004 and January 25, 2005 by Rutgers University.

River Mile 5.3 – Data collected from Rutgers University Buoy #M4.

River Mile 6.7 –Data collected from Rutgers University Buoy #M5.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

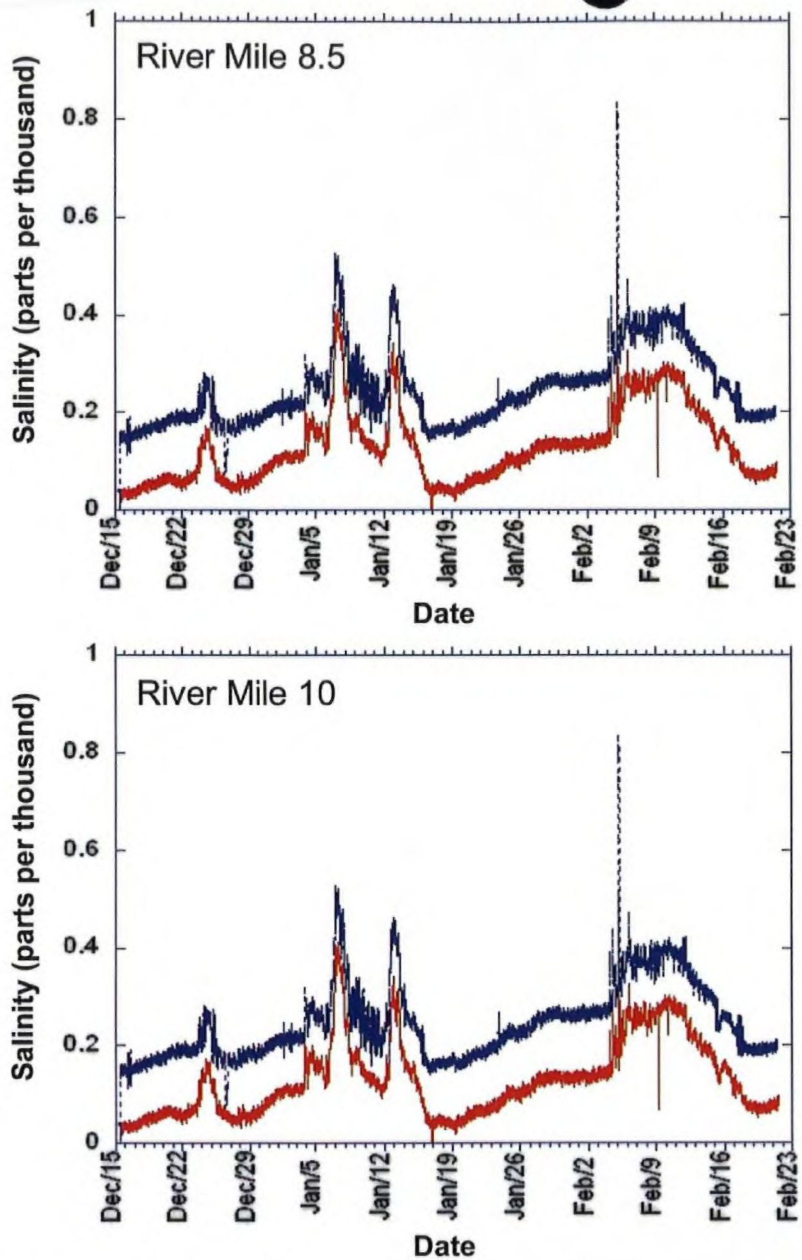
Source for Rutgers University data: http://marine.rutgers.edu/cool/passaic

Temporal Trends in Salinity at River Miles 5.3 and 6.7

Lower Passaic River Restoration Project

Figure 2-2c

September 2006
Pre-Draft



Legend

Salinity measurements collected one meter from the water surface

Salinity measurements collected one meter from the water bottom

Notes

Salinity values were calculated from conductivity, temperature, and depth data recorded by a CTD probe.

Data collected from December 15, 2004 to February 21, 2005 by Malcolm Pirnie, Inc.

River Mile 8.5 – Data collected from Malcolm Pirnie, Inc. Buoy #3.

River Mile 10 – Data collected from Malcolm Pirnie, Inc. Buoy #2.

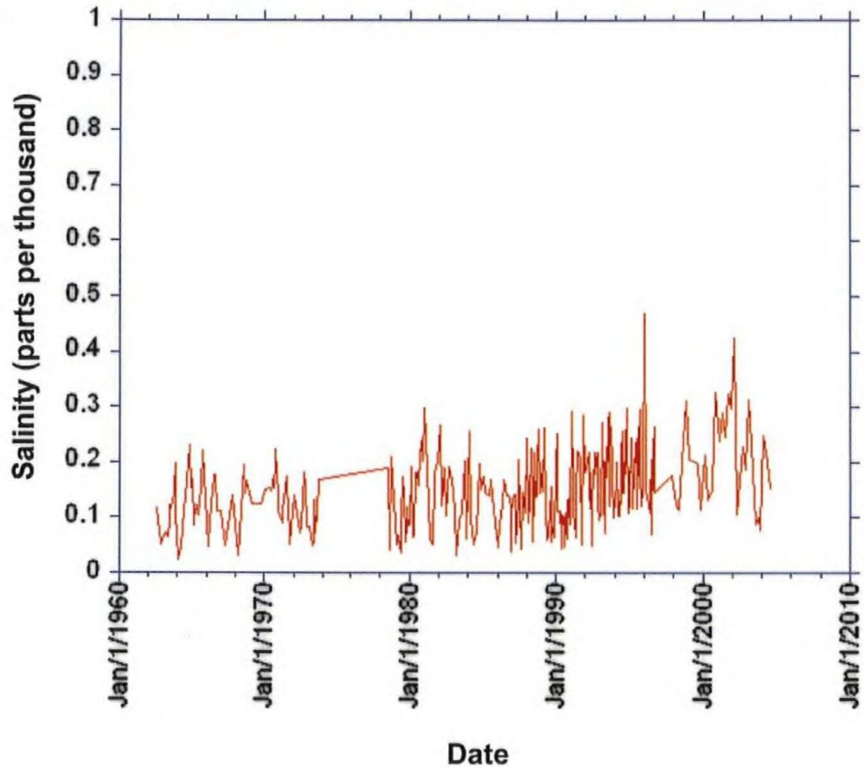
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Temporal Trends in Salinity at River Miles 8.5 and 10

Lower Passaic River Restoration Project

Figure 2-2d

September 2006
Pre-Draft



Legend

Salinity measurements recorded by a U.S. Geological Survey gauging station

Notes

Salinity measurements were taken between July 30, 1962 and August 19, 2004 at the USGS Gauge at Little Falls.

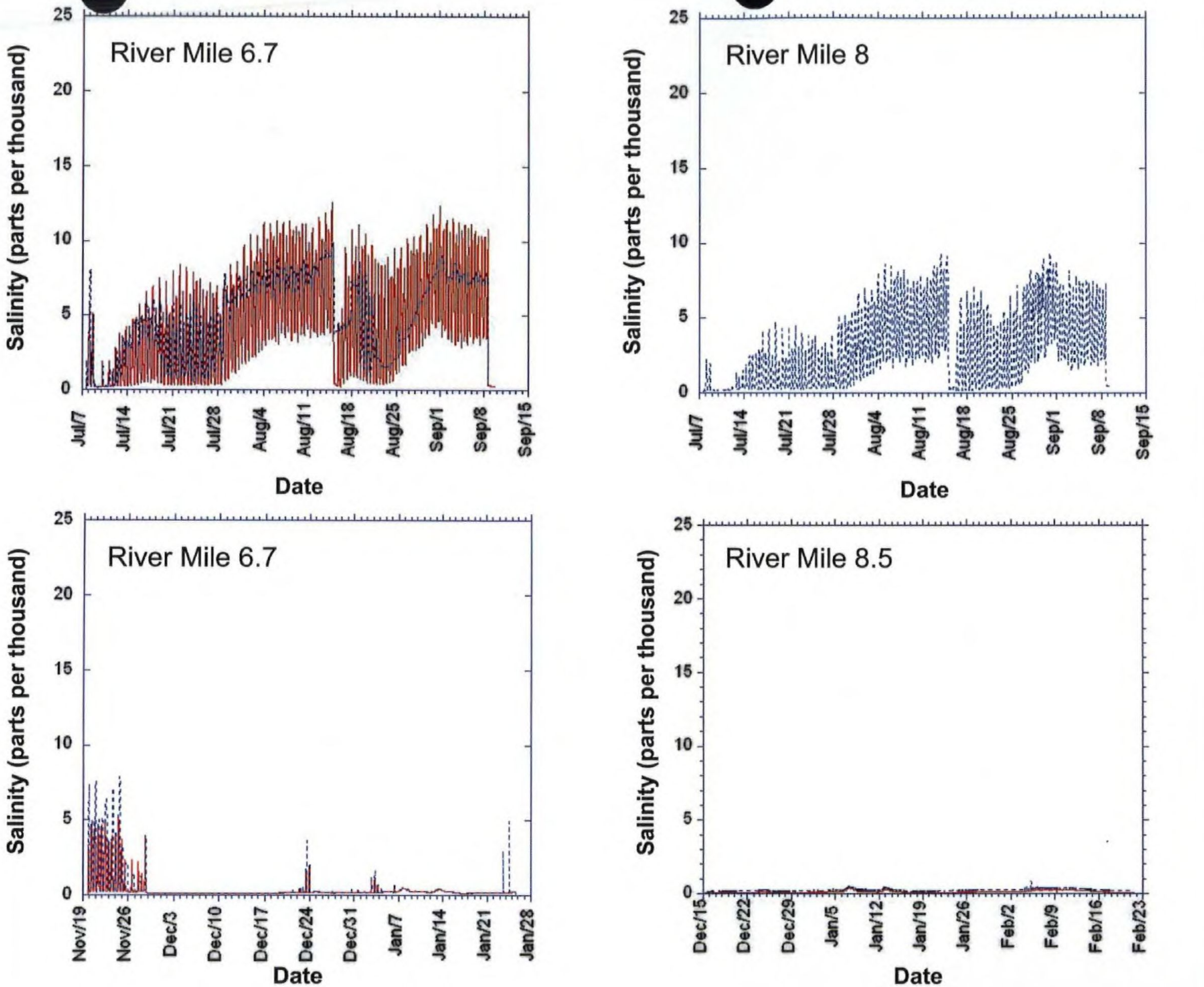
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Temporal Trends in Salinity at U.S. Geological Survey Gauge at Little Falls

Lower Passaic River Restoration Project

Figure 2-2e

September 2006
Pre-Draft



Legend

Salinity measurements collected from the water surface

Salinity measurements collected from the water bottom

Notes

River Mile 6.7 – Data collected from July 8, 2004 to September 10, 2004 at Rutgers University Buoy #M5.

River Mile 8 – Data collected from July 8, 2004 to September 10, 2004 at Rutgers University Buoy #M6.

River Mile 6.7 – Data collected from November 20, 2004 to January 25, 2005 at Rutgers University Buoy #M6.

River Mile 8.5 – Data collected from December 15, 2004 to February 21, 2005 at Malcolm Pirnie, Inc. Buoy #3. Same data as Figure 1-2d on a different scale.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Source for Rutgers University data: http://marine.rutgers.edu/cool/passaic

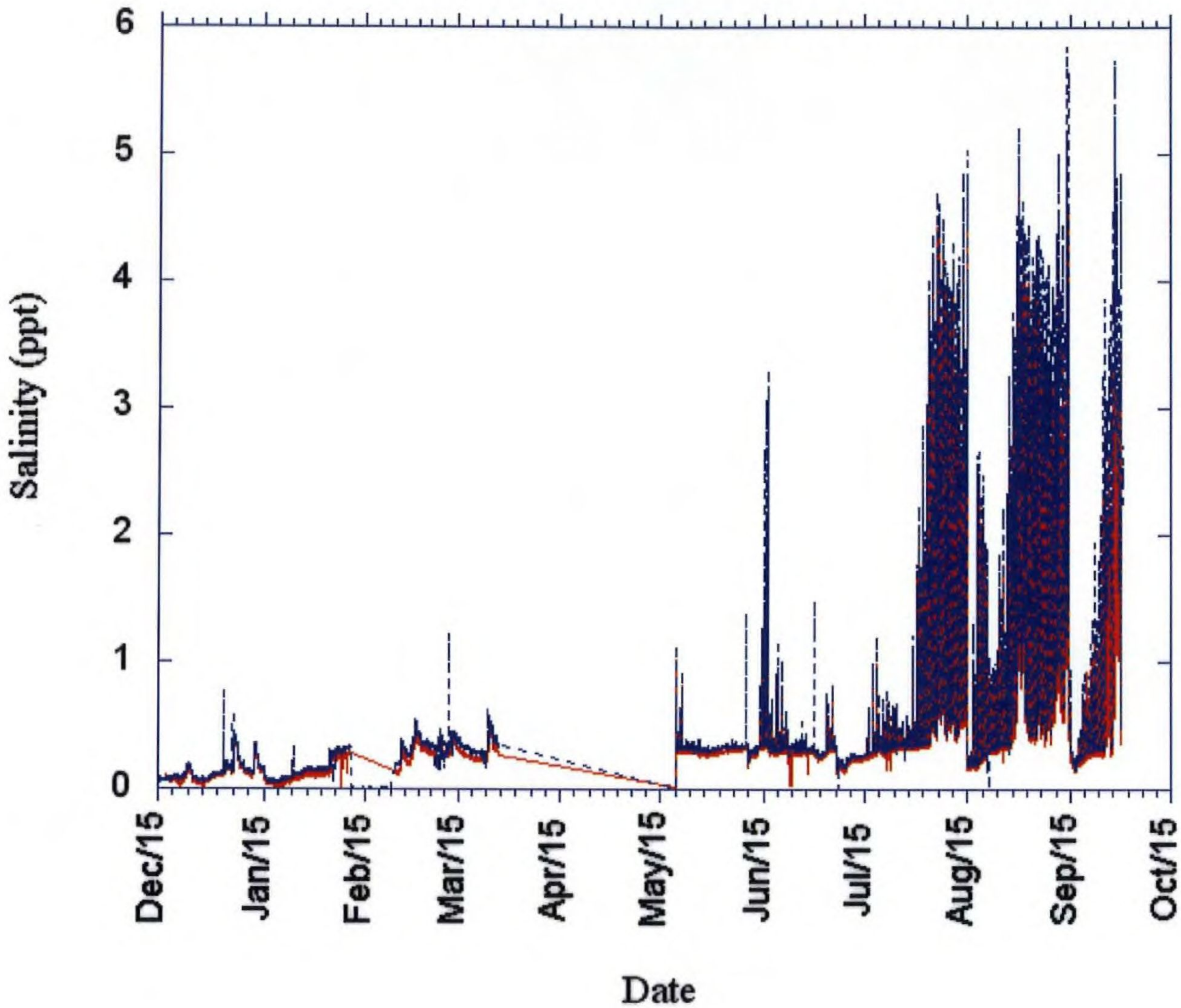
US Army Corps of Engineers

Seasonal Effects on Salinity

Lower Passaic River Restoration Project

Figure 2-2f

September 2006
Pre-Draft



Legend

Salinity measurements collected from the water surface

Salinity measurements collected from the water bottom

Notes

Salinity values were calculated from conductivity, temperature, and depth data recorded by a CTD probe.

Data collected from December 15, 2004 to September 30, 2005 by Malcolm Pirnie, Inc.

River Mile 10 – Data collected from Malcolm Pirnie, Inc. Buoy #2.

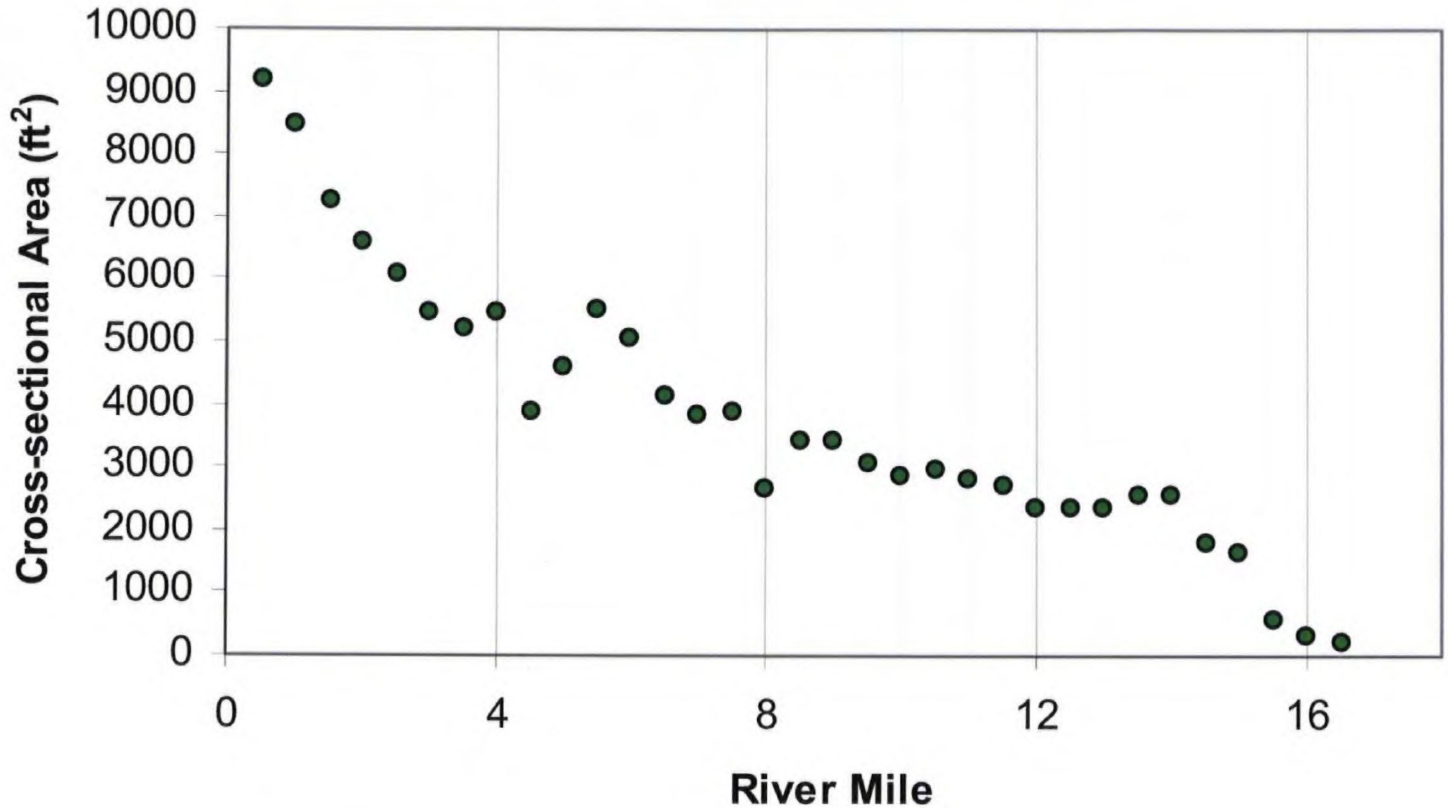
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Temporal Trends in Salinity at River Mile 10

Lower Passaic River Restoration Project

Figure 2-2g

September 2006
Pre-Draft



Legend

● Area (square feet)

Notes

Cross-sectional area estimated from 2004 bathymetric data surveyed by Rogers Survey, Inc.

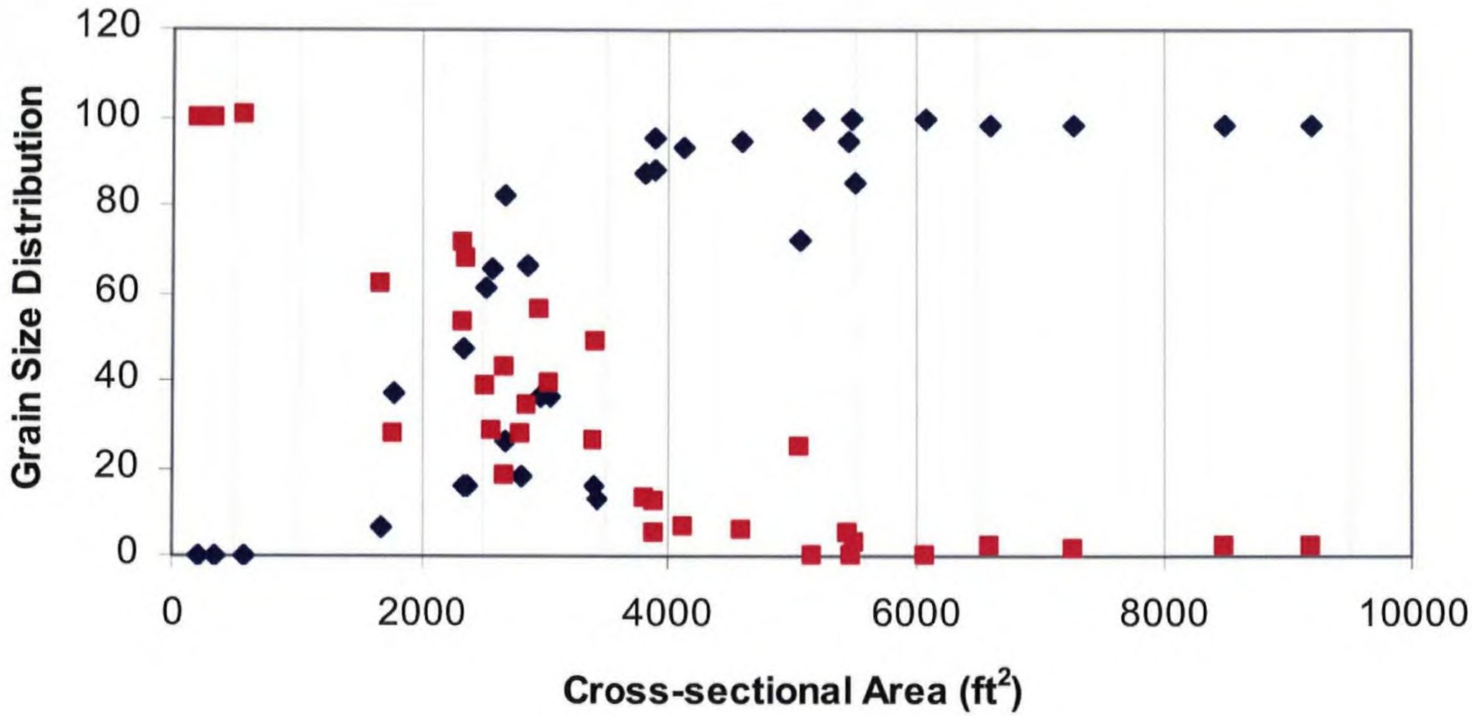
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Cross-Sectional Area vs River Mile

Lower Passaic River Restoration Project

Figure 2-3a

September 2006
Pre-Draft



Legend

- Fine-grained sediment
- Coarse-grained sediment

Notes

Cross-sectional area estimated from 2004 bathymetric data surveyed by Rogers Survey, Inc.

Sediment texture was evaluated based on data interpolated by Aqua Survey, Inc. using side-scan sonar images (Aqua Survey, Inc., 2006). Sediment texture data extends from RM 0 to RM 16.5.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

US Army Corps of Engineers

Sediment Grain Size vs Cross-Sectional Area

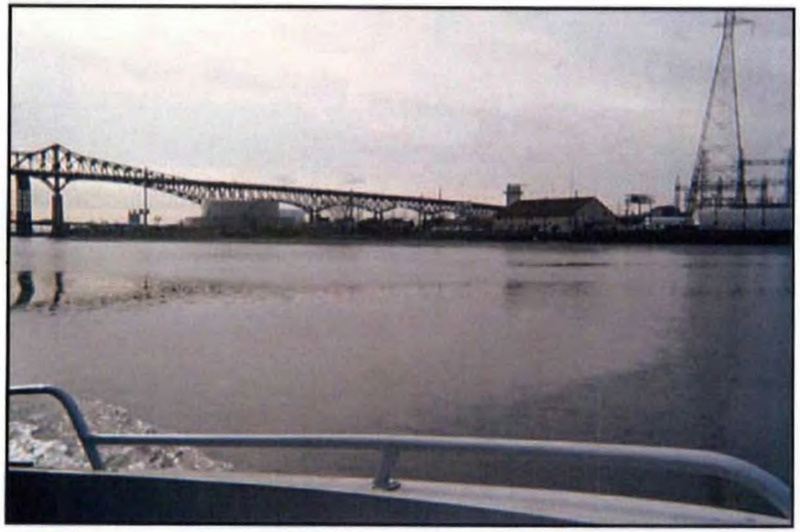
Lower Passaic River Restoration Project

Figure 2-3b

September 2006
Pre-Draft

River Mile 1.4 (left-bank descending) Kearny, NJ

River Mile 1.6 (left-bank descending) Kearny, NJ



River Mile 1.7 (left-bank descending) Kearny, NJ

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

River Mile 2.1 (right-bank descending) Newark, NJ

Photolog of Shoreline Conditions and Surrounding Habitat
Brackish River Section (Part 1)

Lower Passaic River Restoration Project

Figure 2-4a

September 2006
Pre-Draft

River Mile 3.5 (left-bank descending) Newark, NJ

River Mile 4.0 (right-bank descending) Newark, NJ

River Mile 5.1 (right-bank descending) Newark, NJ

River Mile 5.5 (left-bank descending) Harrison, NJ

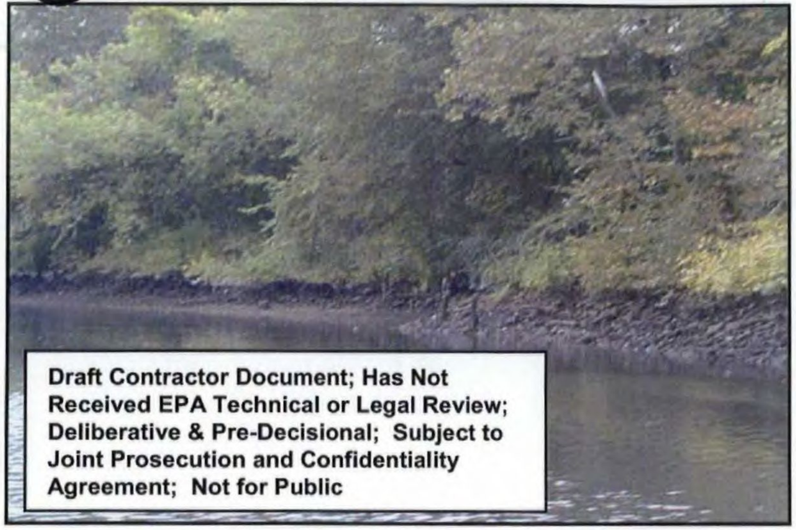
US Army Corps of Engineers

Photolog of Shoreline Conditions and Surrounding Habitat
Brackish River Section (Part 2)

Lower Passaic River Restoration Project

Figure 2-4b

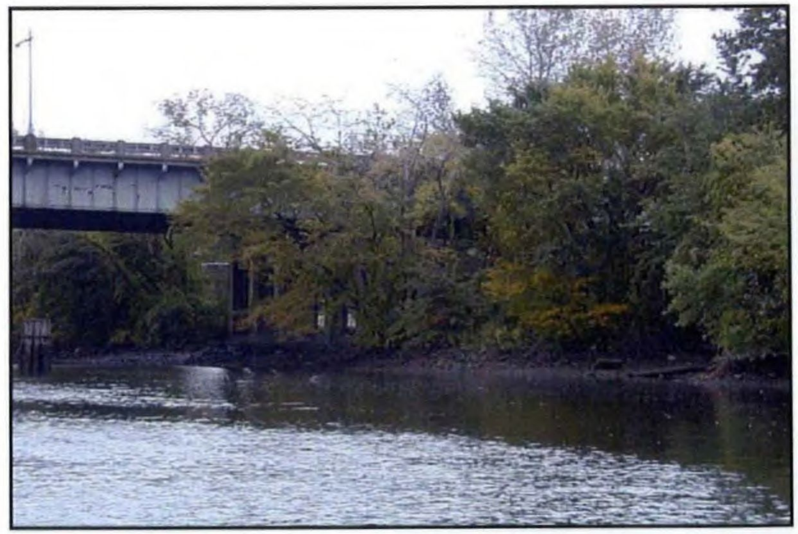
September 2006
Pre-Draft



River Mile 6.3 (left-bank descending) Kearny, NJ

River Mile 6.8 (left-bank descending) Kearny, NJ

River Mile 7.1 (left-bank descending) Kearny, NJ



River Mile 7.8 (right-bank descending) Kearny, NJ

Photolog of Shoreline Conditions and Surrounding Habitat
Transitional River Section

Lower Passaic River Restoration Project

Figure 2-4c

September 2006
Pre-Draft

River Mile 12.8 (right-bank descending) Passaic, NJ

River Mile 15.8 (right-bank descending) Passaic, NJ

River Mile 15.9 (right-bank descending) Passaic, NJ

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

US Army Corps of Engineers	Photolog of Shoreline Conditions and Surrounding Habitat Freshwater River Section (Part 1) *Lower Passaic River Restoration Project*	Figure 2-4d September 2006 Pre-Draft

River Mile 16.6 (left-bank descending) Garfield, NJ

River Mile 17.2 (left-bank descending) Garfield, NJ

River Mile 17.2 (left-bank descending) Garfield, NJ

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

River Mile 17.4 (Dundee Dam) Clifton and Garfield, NJ

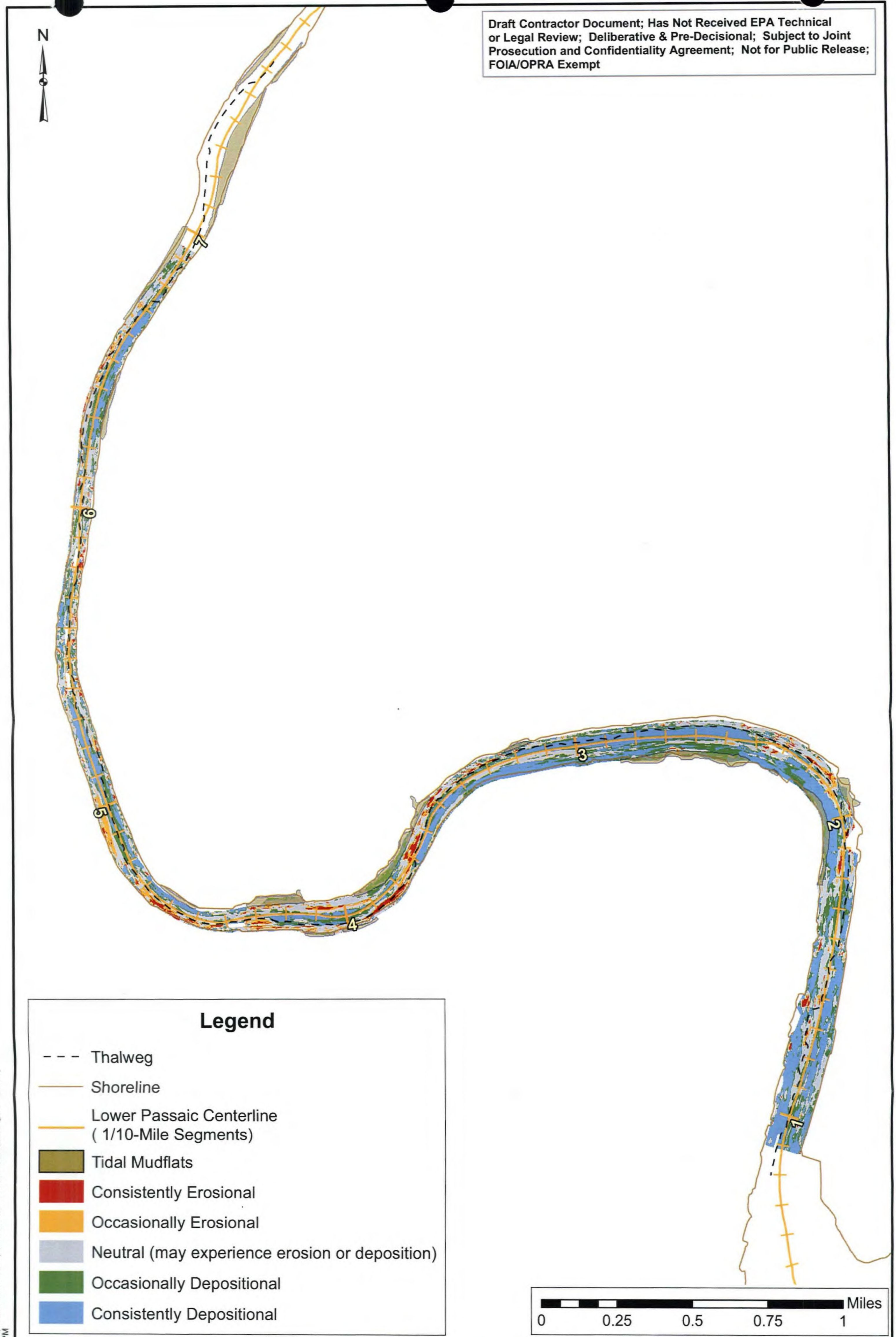
US Army Corp of Engineers

Photolog of Shoreline Conditions and Surrounding Habitat
Freshwater River Section (Part 2)

Lower Passaic River Restoration Project

Figure 2-4e

September 2006
Pre-Draft



Erosional and Depositional Areas (RM 0.9 to RM7)

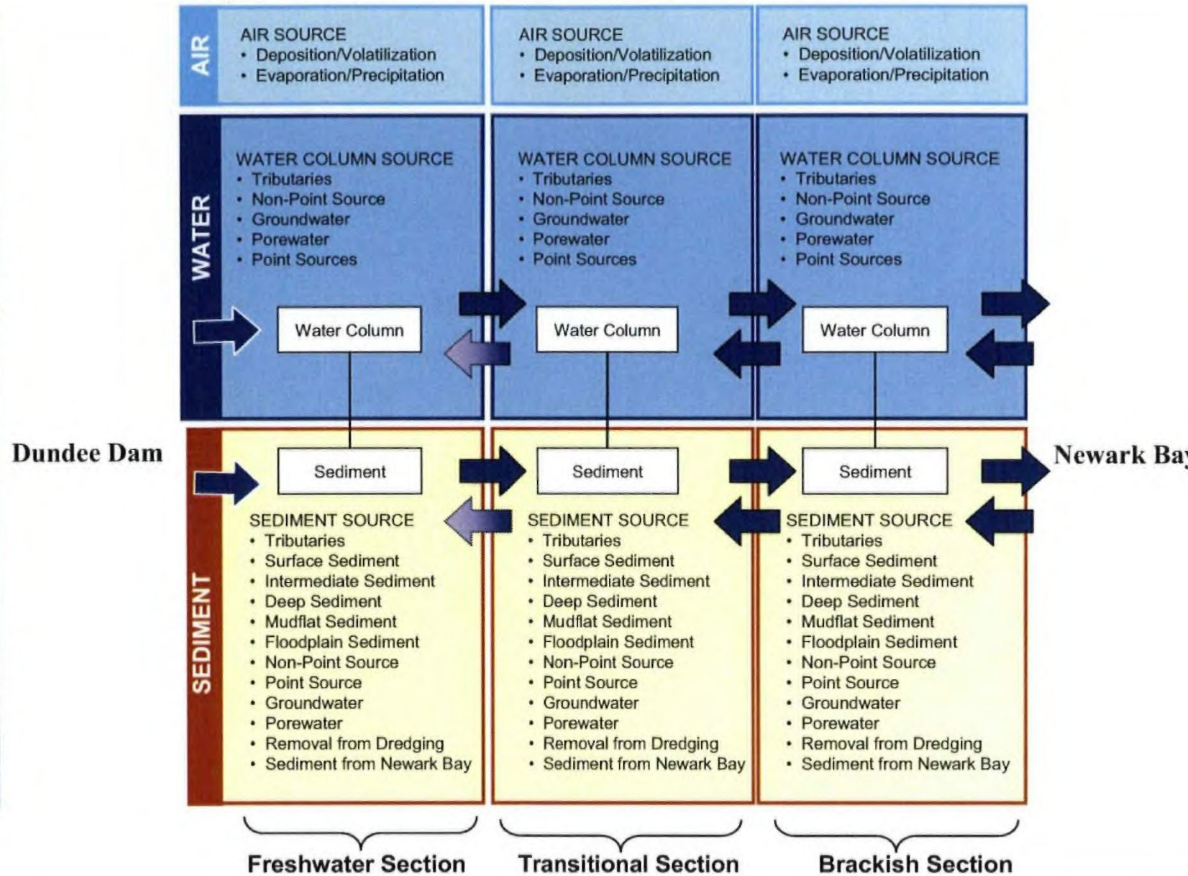
Lower Passaic River Restoration Project

Data Sources : Tierra Solutions Inc., Bathymetric Surveys for 1995,1996,1997,1999 and 2001

FIGURE 4-1

September 2006
Pre-Draft

Map Document: (S:\Projects\PASSAIC\MapDocuments\4553001-CERCLA\Figure4-1.mxd)
8/25/2006 -- 3:55:03 PM



LEGEND

Direction of substantive water flow and sediment transport on the Lower Passaic River

Direction of potential water flow and sediment transport on the Lower Passaic River

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public Release; FOIA/OPRA Exempt

NOTES

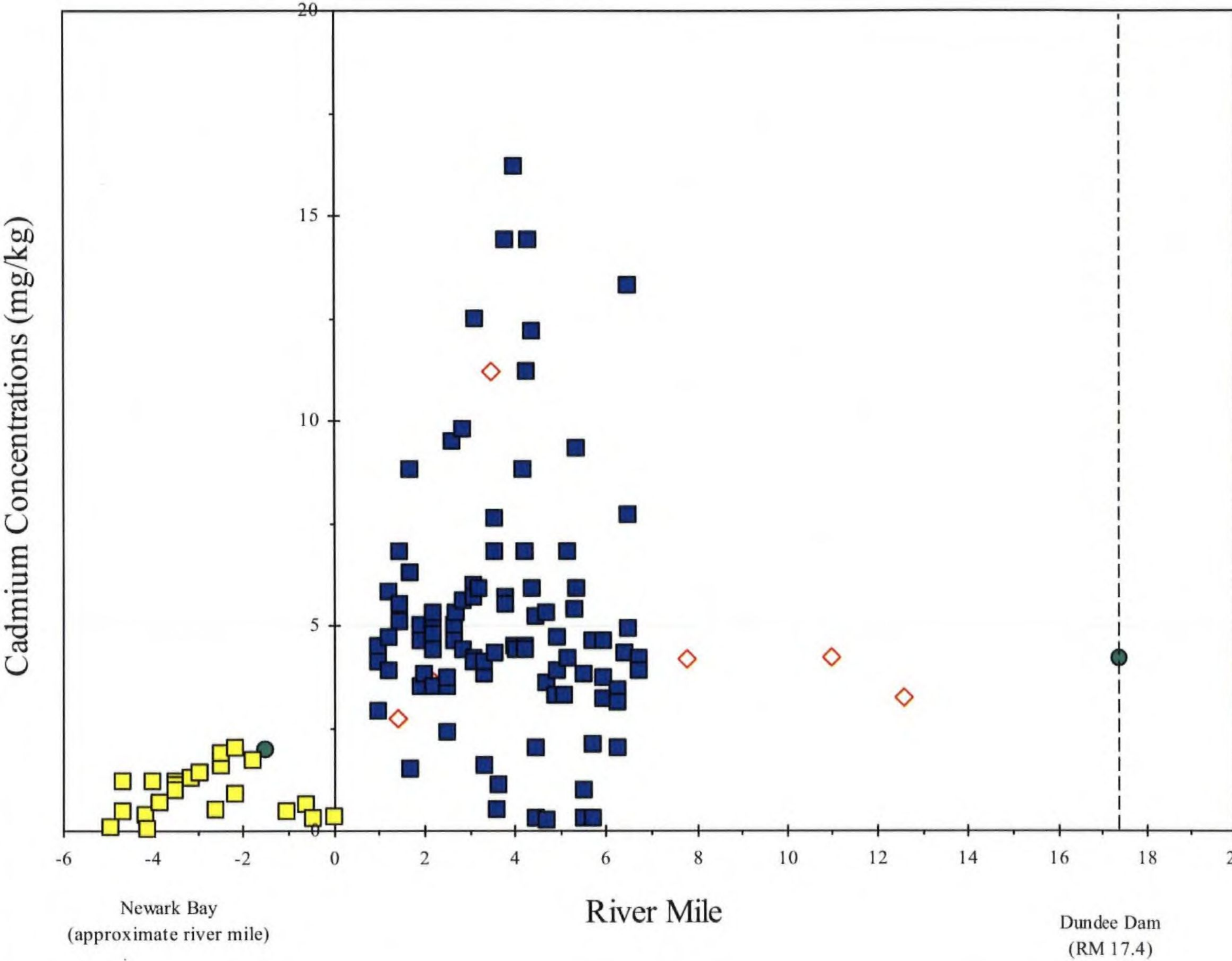
Sources and processes shown in Figure 5-1 are applicable to Figure 5-2; however, for simplicity, arrows presented in Figure 5-1 are not duplicated in Figure 5-2. Note that some sources may be less significant or absent in certain river sections; future iteration of the CSM will prioritize these sources.

The color scheme and boxes used in Figure 5-2 reflect different media, including air (light blue box), water (dark blue box), and sediment (brown box), and they represent the sources, mechanisms, and media depicted in Figure 2-1 and Figure 5-1.

Future iterations of the CSM will prioritize these sources.

Input to Human Health and Ecological Evaluations

US Army Corp of Engineers	**Sources in Each River Section**	Figure 5-2
	Lower Passaic River Restoration Project	September 2006 Pre-Draft



Legend

- Malcolm Pirnie, Inc. (2005)
- Tierra Solutions, Inc. (2005)
- Tierra Solutions, Inc. (1995)
- Bopp et al., 2006 (1985-1986)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (not validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

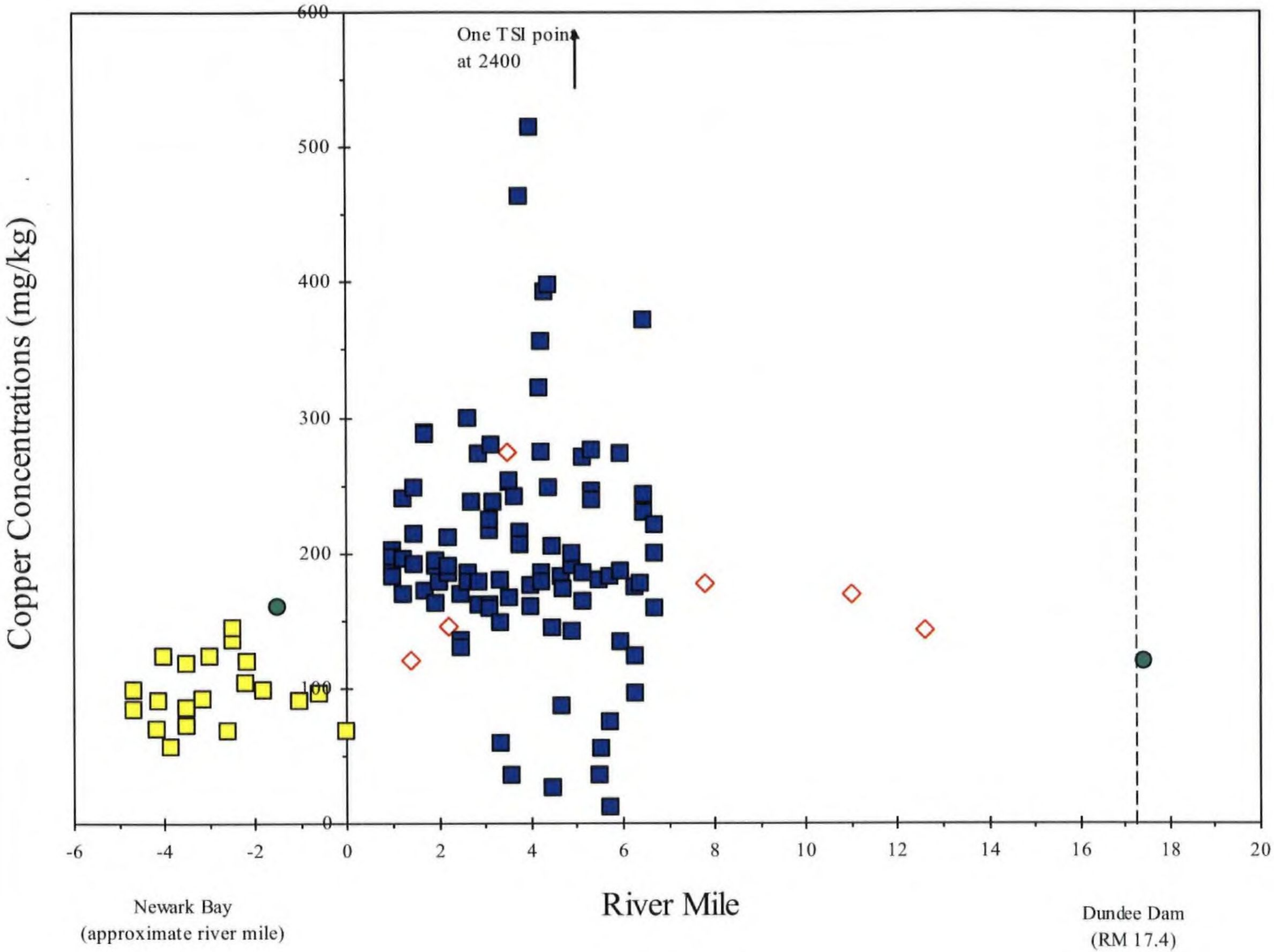
US Army Corps of Engineers

Comparison of Cadmium Concentrations 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3a

September 2006
Pre-Draft



Legend

- Malcolm Pirnie, Inc. (2005)
- Tierra Solutions, Inc. (2005)
- Tierra Solutions, Inc. (1995)
- Bopp et al., 2006 (1985-1986)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (not validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

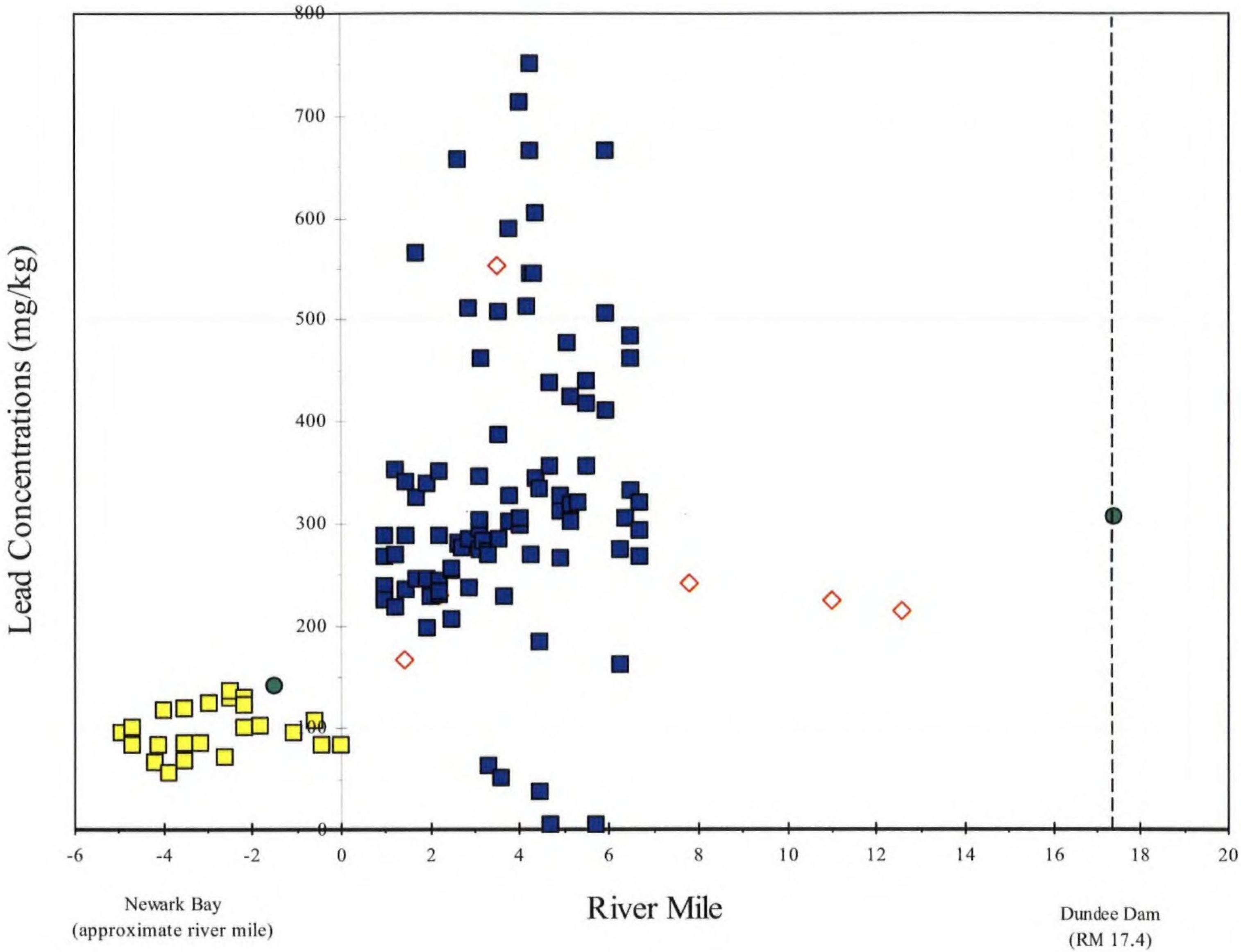
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Comparison of Copper Concentrations 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3b

September 2006
Pre-Draft



Legend

- ◇ Malcolm Pirnie, Inc. (2005)
- ■ Tierra Solutions, Inc. (2005)
- ■ Tierra Solutions, Inc. (1995)
- ● Bopp et al., 2006 (1985-1986)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (not validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

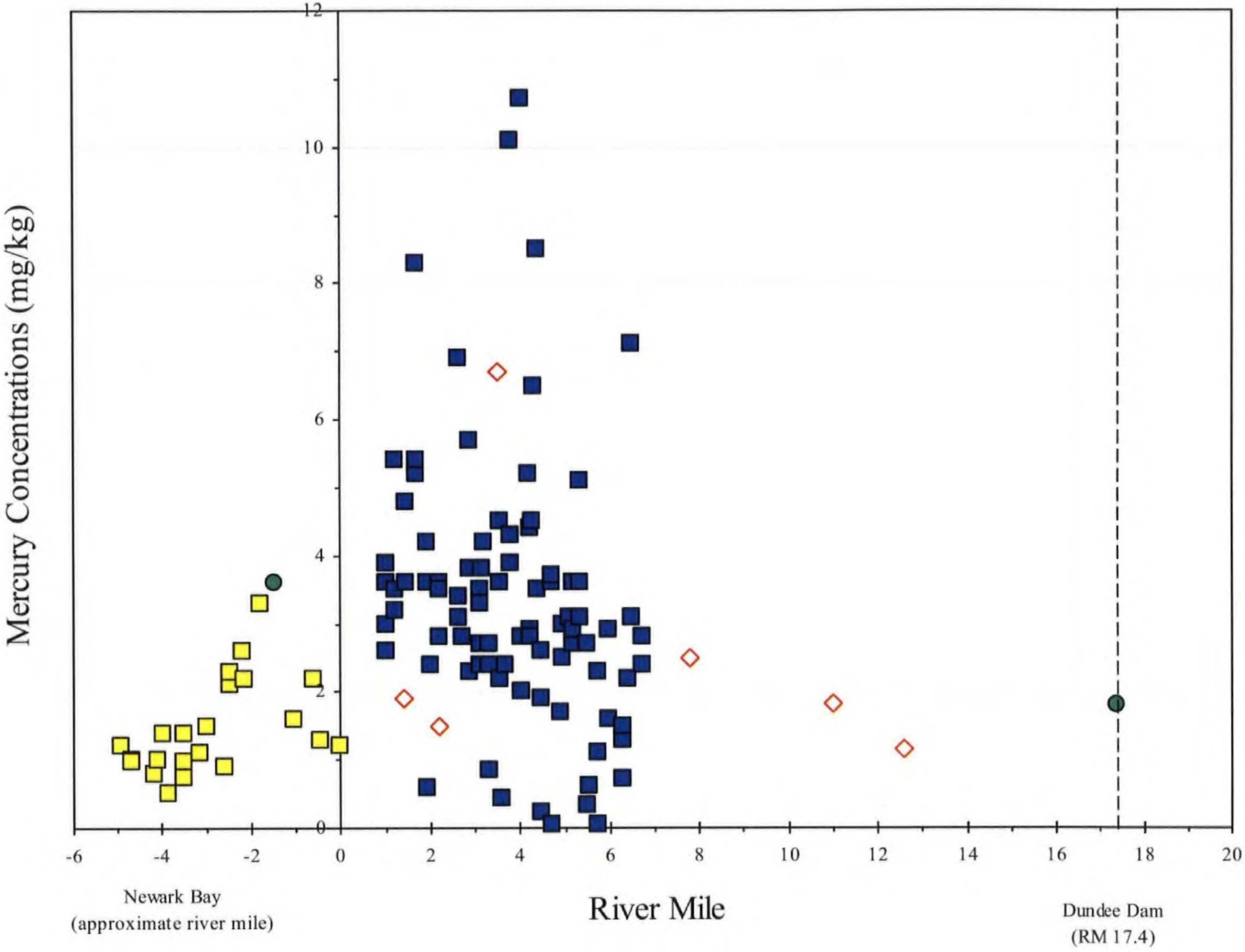
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Comparison of Lead Concentrations 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3c

September 2006
Pre-Draft



Legend

- Malcolm Pirnie, Inc. (2005)
- Tierra Solutions, Inc. (2005)
- Tierra Solutions, Inc. (1995)
- Bopp et al., 2006 (1985-1986)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (not validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

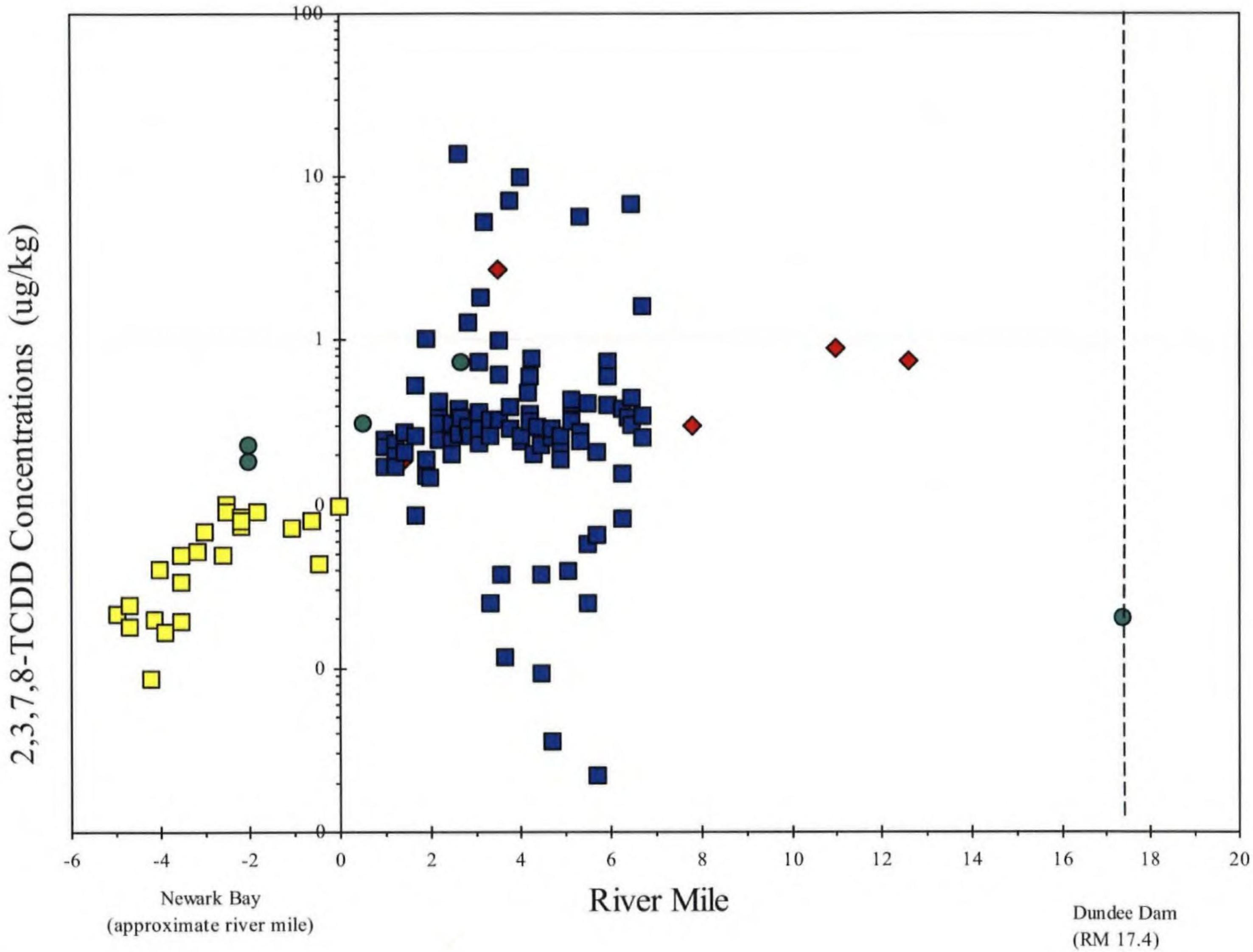
US Army Corps of Engineers

Comparison of Mercury Concentrations 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3d

September 2006
Pre-Draft



Legend

- Malcolm Pirnie, Inc. (2005)
- Tierra Solutions, Inc. (2005)
- Tierra Solutions, Inc. (1995)
- Bopp et al., 2006 (1985-1986)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

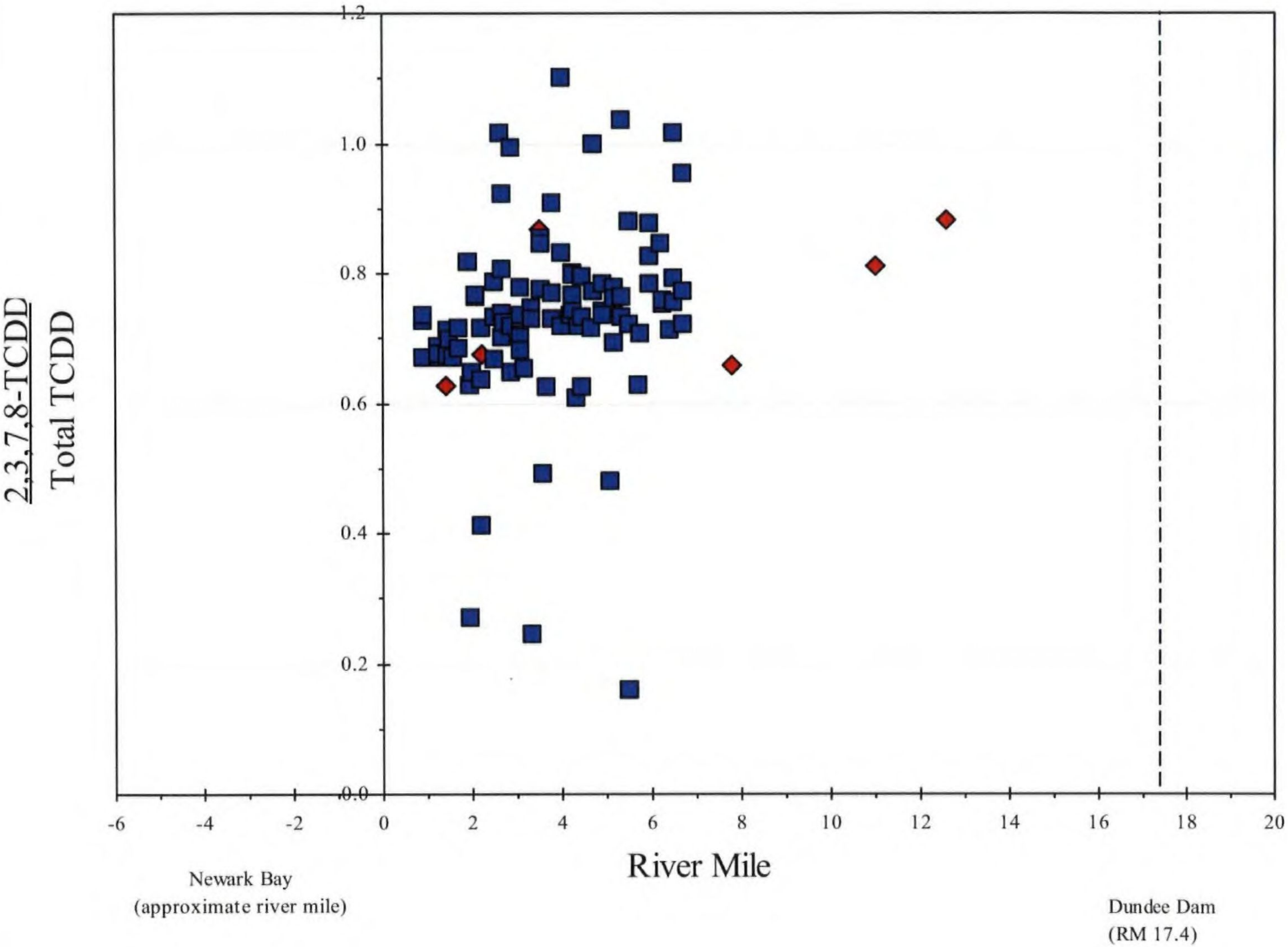
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Comparison of 2,3,7,8-TCDD Concentrations 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3e

September 2006
Pre-Draft



Legend

- Malcolm Pirnie, Inc. (2005)
- Tierra Solutions, Inc. (1995)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

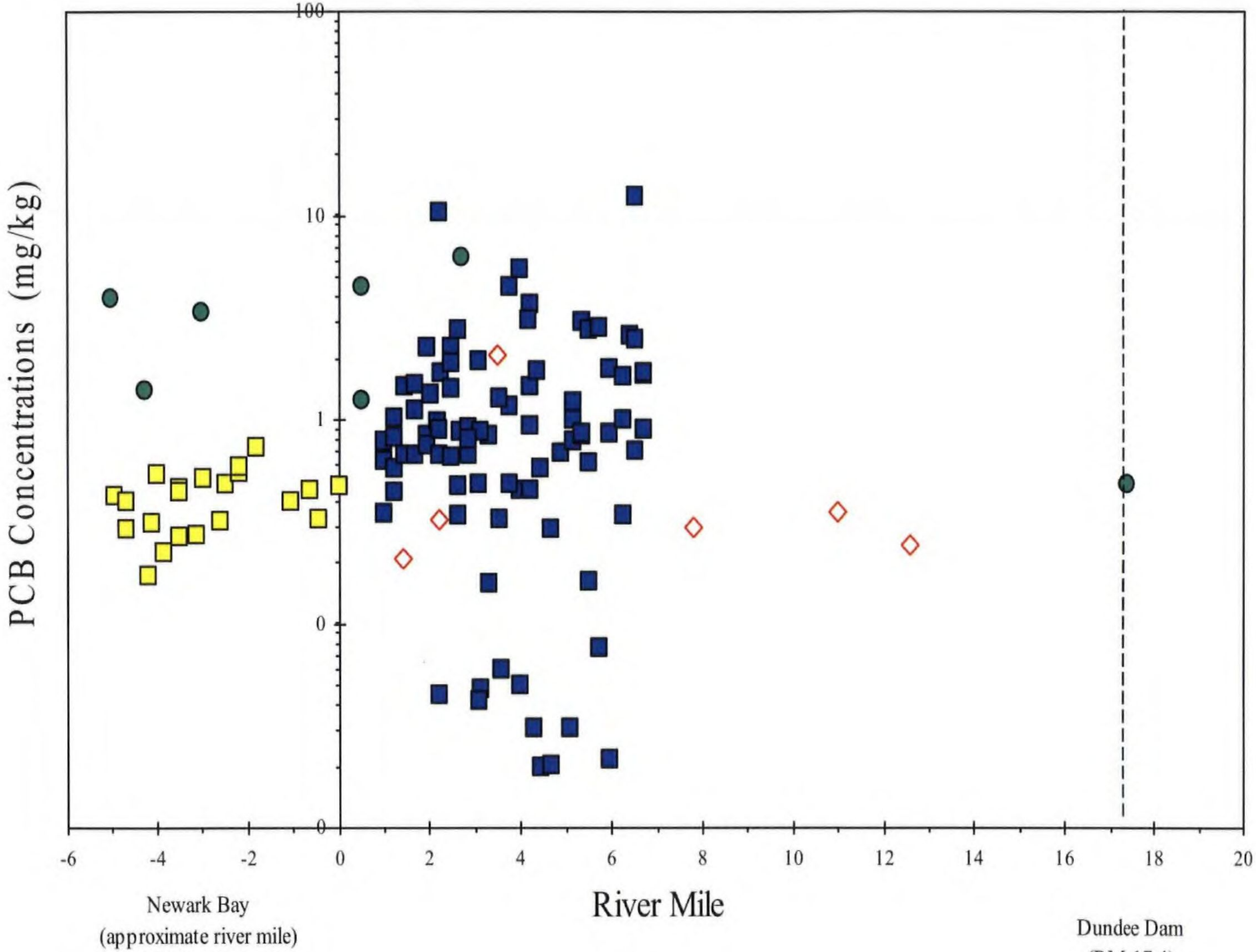
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Comparison of 2,3,7,8-TCDD Ratio 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3f

September 2006
Pre-Draft



Legend

- Malcolm Pirnie, Inc. (2005)
- Tierra Solutions, Inc. (2005)
- Tierra Solutions, Inc. (1995)
- Bopp et al., 2006 (1985-1986)

Notes

Malcolm Pirnie, Inc. Data Source: USEPA 2005-2006 Sampling Program (not validated).

Tierra Solutions, Inc. Data Source: 2005 Newark Bay Phase I Investigation and 1995 TSI Dataset

Bopp Data Source: "Contaminant Chronologies from Hudson River Sedimentary Records," Bopp et al.

Non-detect (lab qualifier containing a U) plotted as half the reported value.

Surface concentrations represent a depth of 0 to <1 foot.

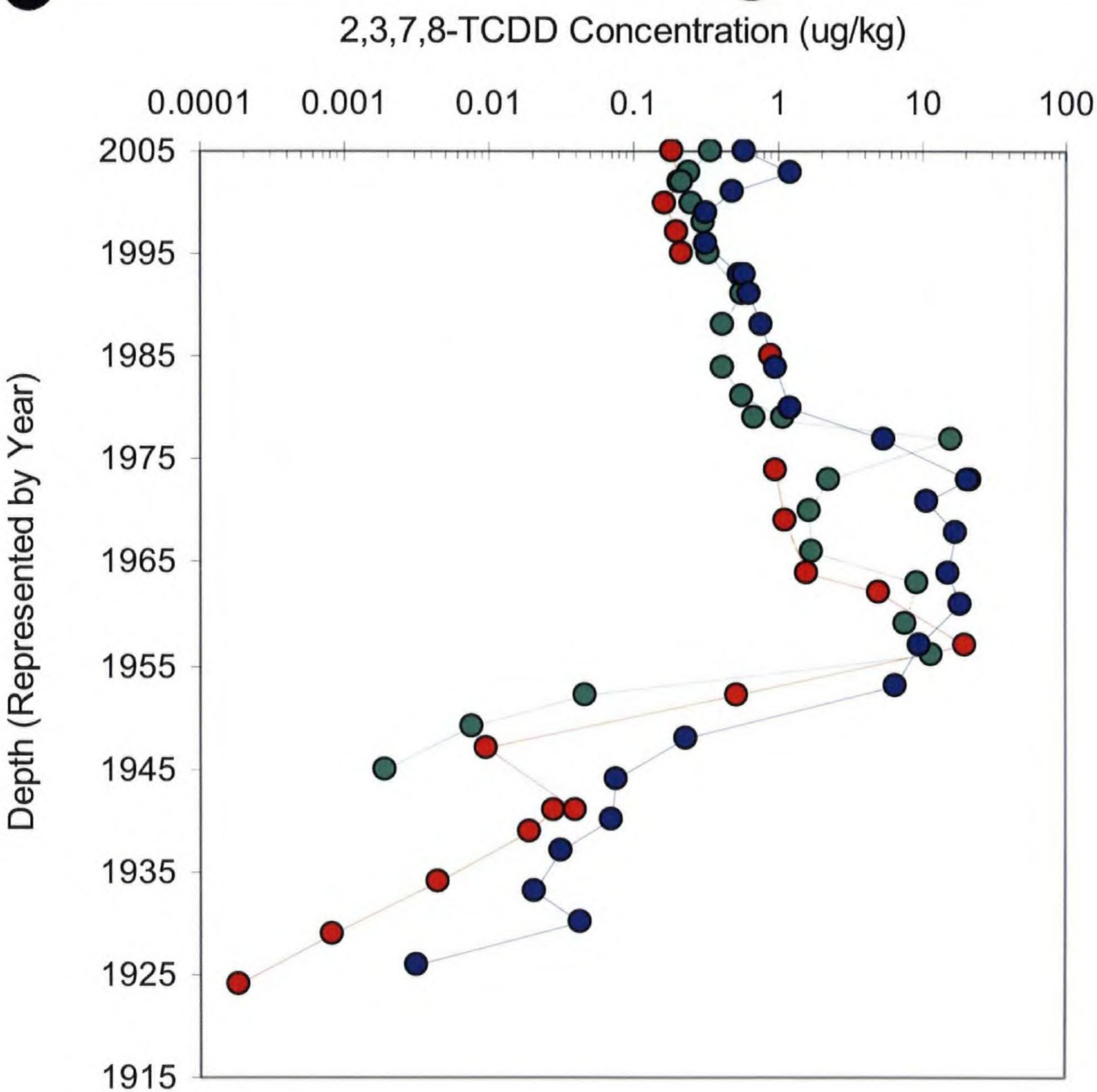
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Comparison of PCB Concentrations 1985, 1995, and 2005

Lower Passaic River Restoration Project

Figure 5-3g

September 2006
Pre-Draft



Legend

- 2,3,7,8-TCDD at RM 1.4
- 2,3,7,8-TCDD at RM 2.2
- 2,3,7,8-TCDD at RM 11

Notes

2005 Malcolm Pirnie, Inc. High Resolution Sediment Core Programs.

The data used is not validated.

Depositional years calculated using Cesium-137 concentrations.

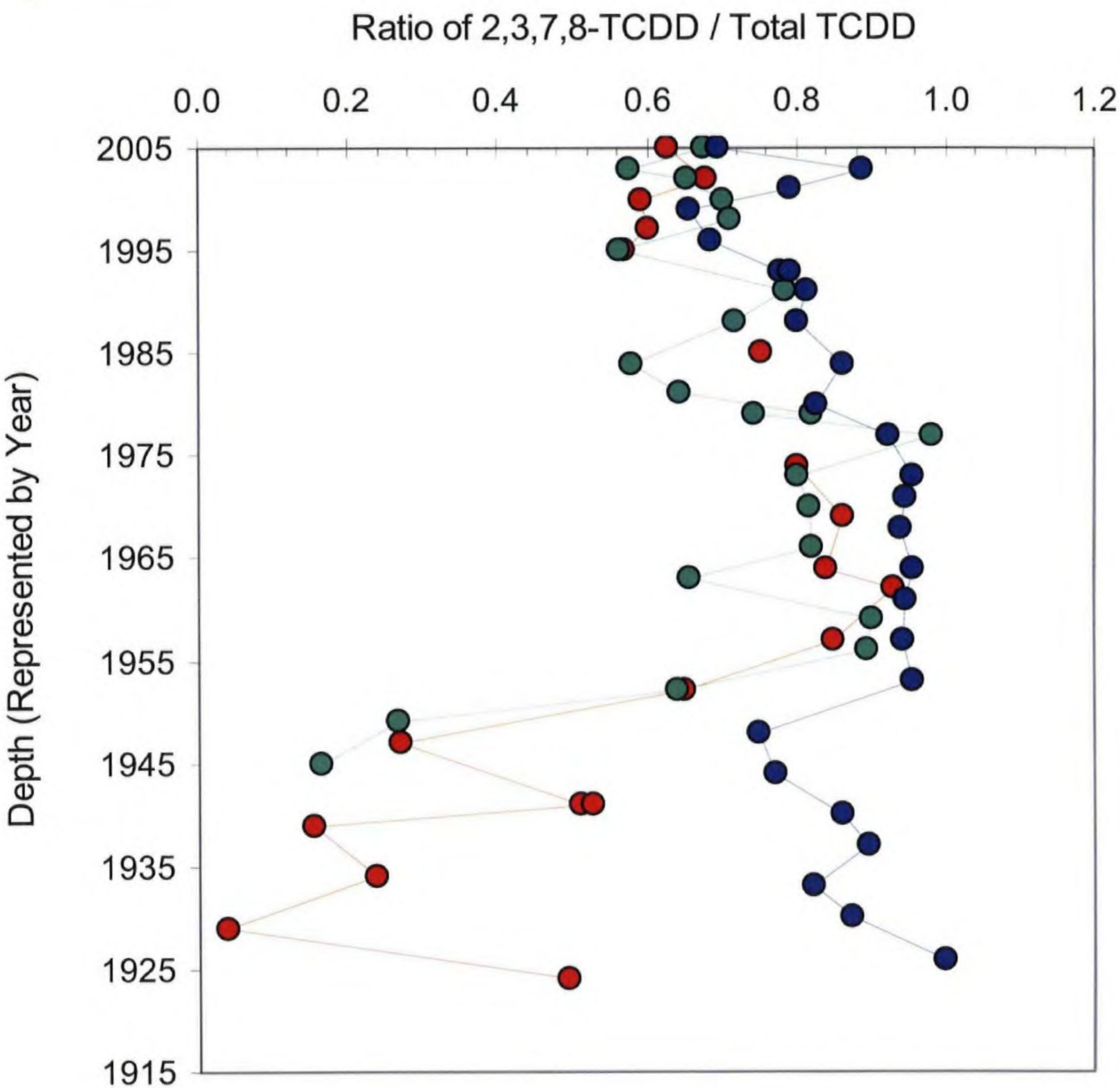
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Downcore Profiles of 2,3,7,8-TCDD at RM 1.4, RM 2.2, and RM 11

Lower Passaic River Restoration Project

Figure 5-4a

September 2006
Pre-Draft



Legend

- Ratio at RM 1.4
- Ratio at RM 2.2
- Ratio at RM 11

Notes

2005 Malcolm Pirnie, Inc. High Resolution Sediment Core Programs.

The data used is not validated.

Depositional years calculated using Cesium-137 concentrations.

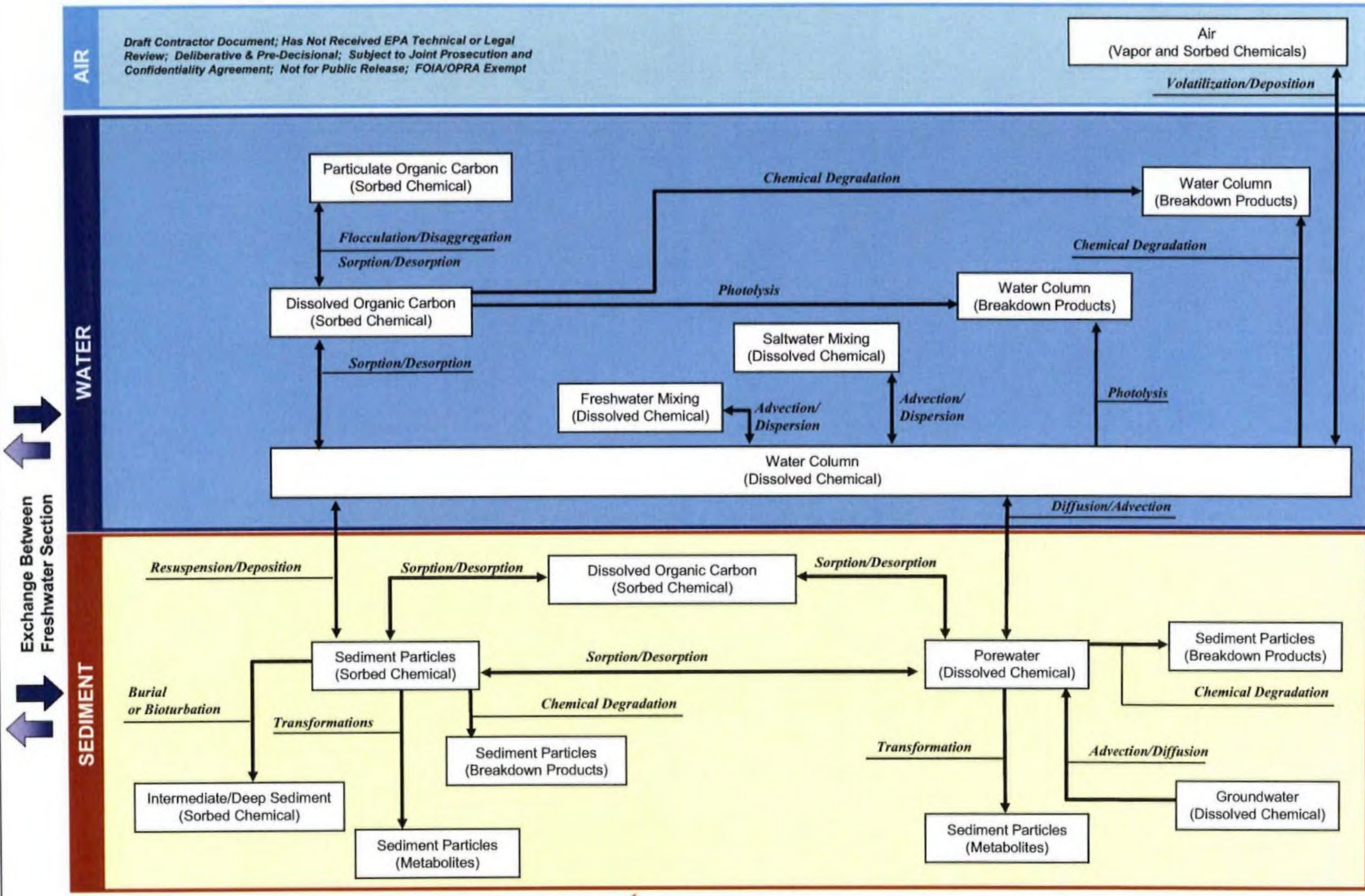
Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public

Downcore Profiles of 2,3,7,8-TCDD at RM 1.4, RM 2.2, and RM 11

Lower Passaic River Restoration Project

Figure 5-4b

September 2006
Pre-Draft



NOTES

Figure 6-1 is intended to depict substantive chemical processes that affect the transport of contaminants. Some chemical processes may be less significant or absent in certain river sections. Future iterations of the CSM will prioritize these processes. For simplicity, physical process shown on Figures 5-1 and 5-2 are not duplicated in this figure. Note that the biological processes are depicted in subsequent figures.

The color scheme and boxes used in Figure 6-1 reflect different media, including air (light blue box), water (dark blue box), and sediment (brown box), and they represent the sources, mechanisms, and media depicted in Figures 2-1, 5-1, and 5-2.

LEGEND for Figures 6-1 and 6-2

Inventory with chemical state marked in parentheses, where appropriate

Abiotic reactions or pathways connecting associated inventories

Biotic reactions or pathways connecting associated inventories (see Fig. 6-2)

Direction of substantive water flow and sediment transport on the Lower Passaic River

Direction of potential water flow and sediment transport on the Lower Passaic River

US Army Corp of Engineers

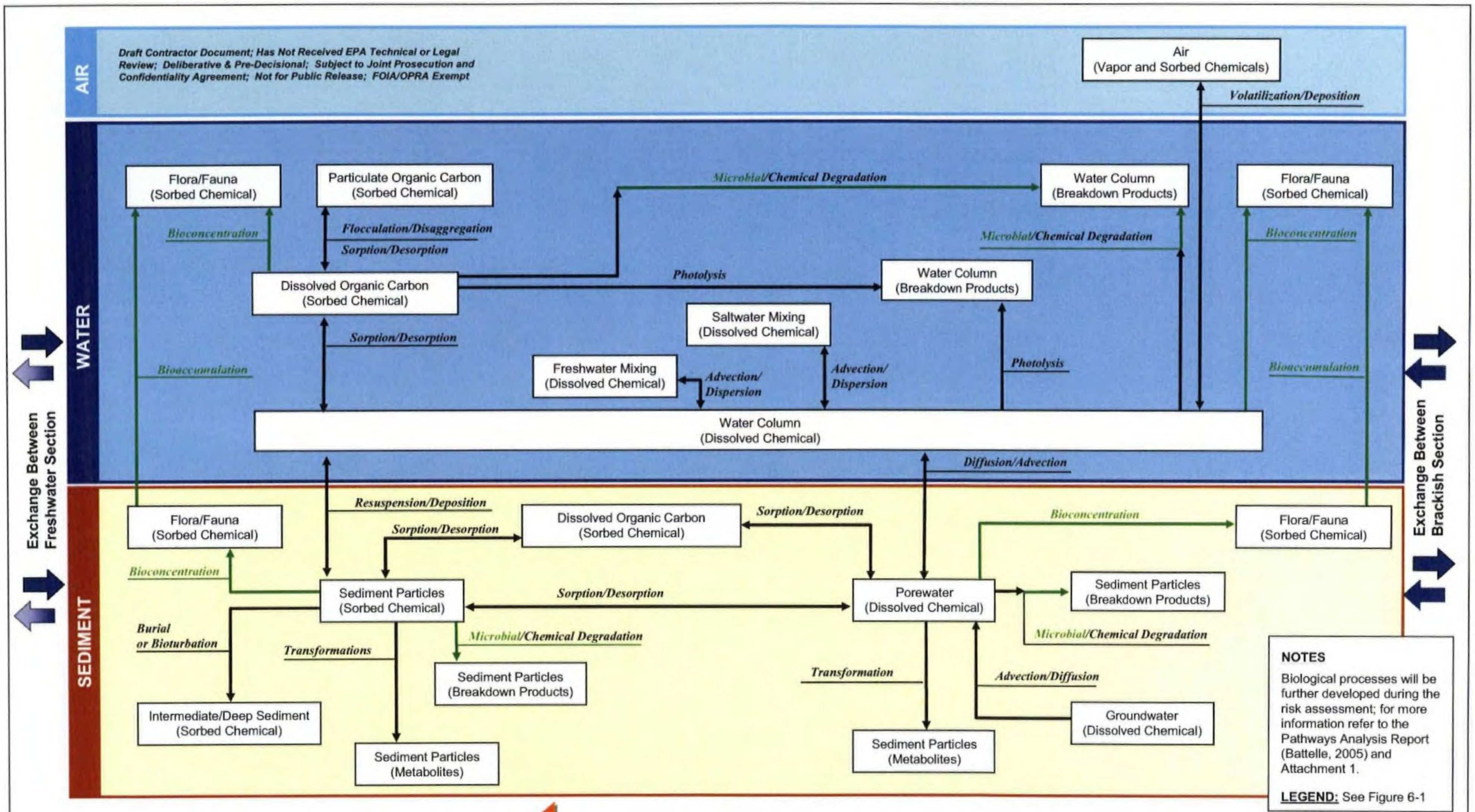
Input to Human Health and Ecological Evaluations

Chemical Fate and Transport Processes in Transitional Section

Figure 6-1

Lower Passaic River Restoration Project

September 2006
Pre-Draft



US Army Corp of Engineers

Input to Human Health and Ecological Evaluations

Chemical and Biological Fate and Transport Processes in Transitional Section

Figure 6-2

Lower Passaic River Restoration Project

September 2006
Pre-Draft

Attachment 1

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public Release; FOIA/OPRA Exempt

Excerpt from Battelle, 2005. "Pathways Analysis Report." Lower Passaic River Restoration Project. July 2005.

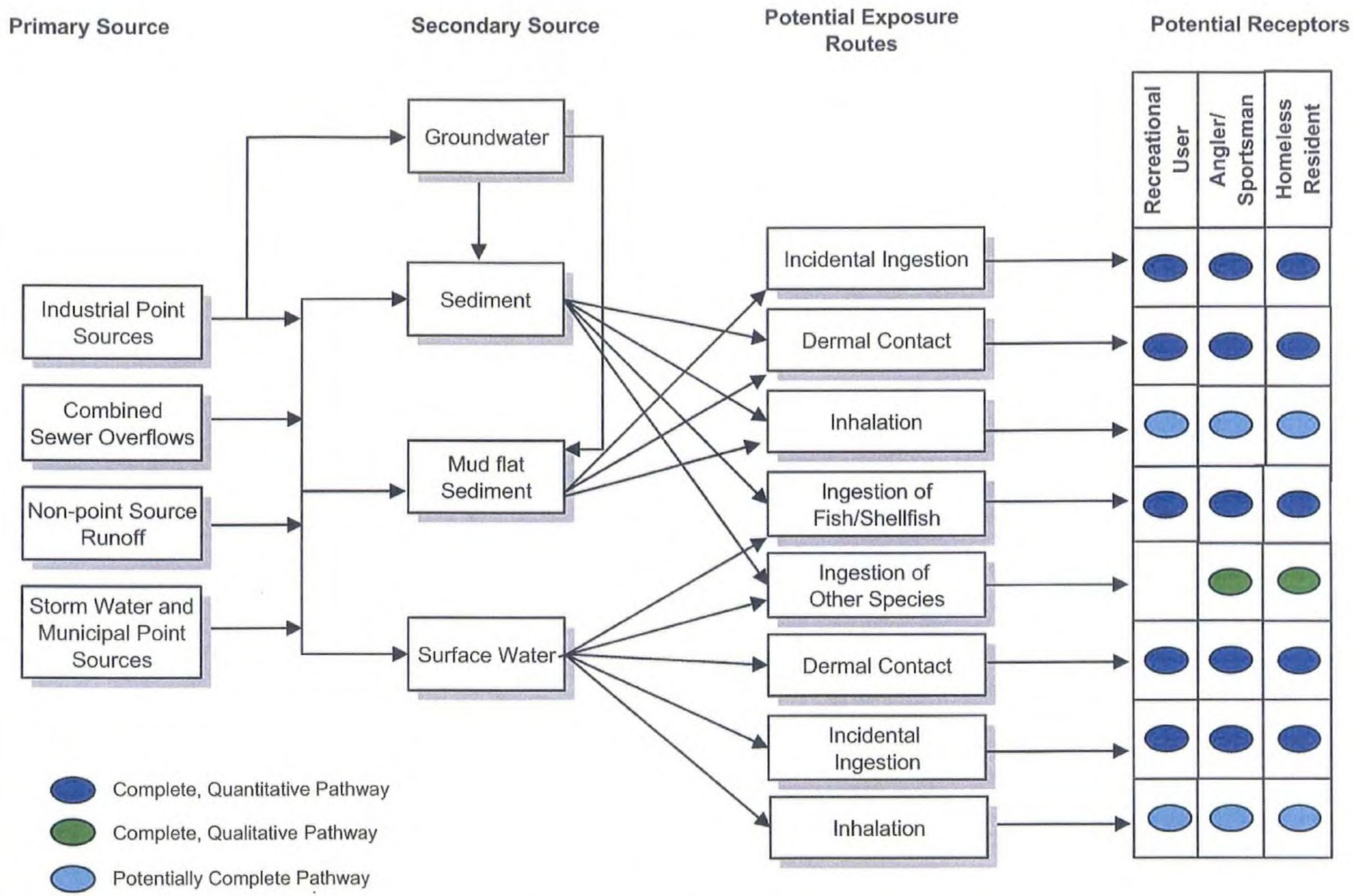


Figure 5. Human Health Conceptual Site Model.

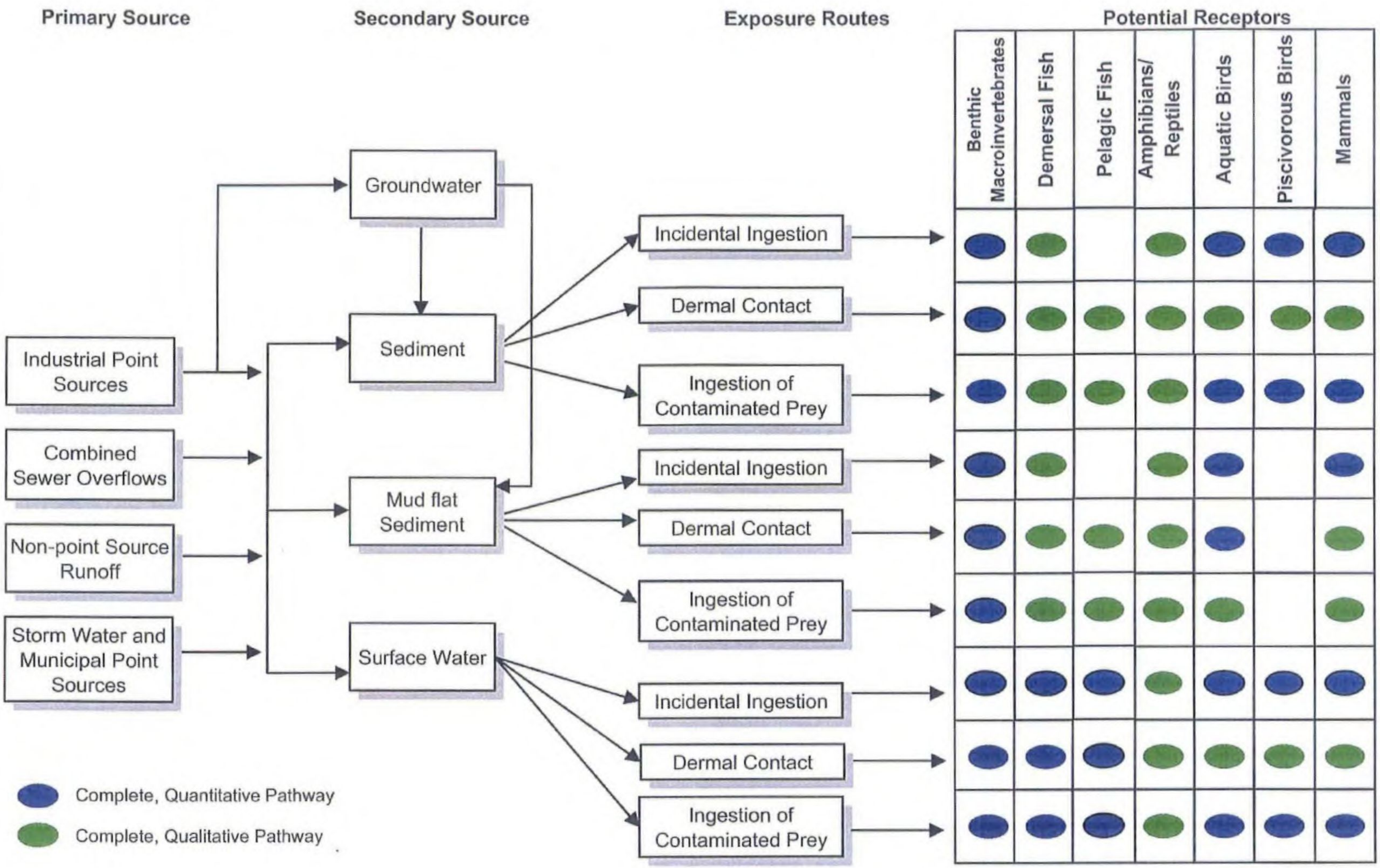


Figure 6. Ecological Conceptual Site Model.

Attachment 2

Draft Contractor Document; Has Not Received EPA Technical or Legal Review; Deliberative & Pre-Decisional; Subject to Joint Prosecution and Confidentiality Agreement; Not for Public Release; FOIA/OPRA Exempt

ANALYSIS OF GROUNDWATER CONTRIBUTION TO LOWER PASSAIC RIVER CONTAMINATION

TABLE OF CONTENTS

1.0 Introduction 1-1
2.0 Baseflow Estimation 2-1
2.1 River Hydrology 2-1
2.2 Selection of a Comparable Watershed 2-1
2.3 Analysis of Permitted Discharges 2-2
2.4 Determination of Baseflow in Elizabeth River 2-3
2.5 Comparison to Second and Third Rivers 2-4
3.0 Estimation of Groundwater Effects 3-1
3.1 Calculating Surface Water Flows 3-1
3.2 Organics 3-5
3.2.1 Estimating River Concentrations 3-5
3.2.2 Solubilities 3-8
3.2.3 Mixing Equations 3-9
3.3 Metals 3-12
3.3.1 Estimating River Concentrations 3-12
3.3.2 Solubilities 3-12
3.3.3 Mixing Equation 3-14
4.0 Conclusion 4-1

ANALYSIS OF GROUNDWATER CONTRIBUTION TO LOWER PASSAIC RIVER CONTAMINATION

LIST OF FIGURES

Figure 2-1: Idealized Cross-section of the Lower Passaic River
Figure 2-2: Drainage Areas and USGS Streamflow Gauges near the Lower Passaic River
Figure 2-3: Drainage Areas and USGS Streamflow Gauges for Calculating Baseflow
Figure 2-4: NJPDES Permitted Locations
Figure 2-5: Elizabeth River Average Daily Streamflow – 1983
Figure 2-6: Elizabeth River Average Daily Streamflow with Estimated Baseflow – 1983
Figure 2-7: Minimum, Average and Maximum Estimated Baseflow for Elizabeth River 1922-2005
Figure 2-8: Comparison of Average Estimated Recharge to Elizabeth River, Second River and Third River
Figure 3-1: Possible Groundwater Impact on the Lower Passaic River – 2,3,7,8-TCDD
Figure 3-2: Possible Groundwater Impact on the Lower Passaic River – DDT
Figure 3-3: Possible Groundwater Impact on the Lower Passaic River – PAH
Figure 3-4: Possible Groundwater Impact on the Lower Passaic River – PAH (detections only)
Figure 3-5: Possible Groundwater Impact on the Lower Passaic River – PCB
Figure 3-6: Groundwater Contamination Areas with Organic Solvents
Figure 3-7: Groundwater Contamination Areas with PCB, DDT, or Benzo[a]pyrene
Figure 3-8: Possible Groundwater Impact on the Lower Passaic River – Lead
Figure 3-9: Possible Groundwater Impact on the Lower Passaic River – Mercury
Figure 3-10: Possible Groundwater Impact on the Lower Passaic River – Methylmercury
Figure 3-11: Possible Groundwater Impact on the Lower Passaic River – Arsenic
Figure 3-12: Groundwater Contamination Areas with Metals

Ex. 5: predecisional and deliberative

Pages 1-1 to 4-2 Redacted; all figures redacted